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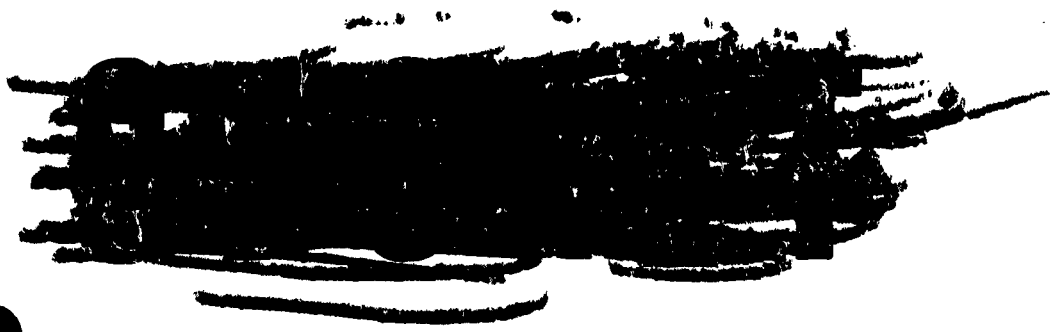

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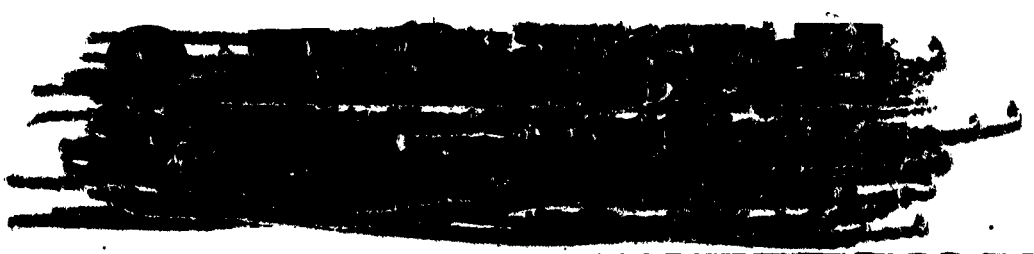

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INFANTRY AND AIRCRAFT WEAPONS DIVISION

REPORT ON

FRAGMENTATION OF PROJECTILE, ATOMIC, 279-MM, PRACTICE, SPOTTING, XM390, COMPOSITION B LOADED (C)

First Report on Ordnance Project No. TN2-8051

(D. A. Project No. 512-15-018)

J. T. DEMPSEY

MAY 1960

Aberdeen Proving Ground
Maryland

DEVELOPMENT AND PROOF SERVICES
ABERDEEN PROVING GROUND
MARYLAND

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FRAGMENTATION OF PROJECTILE, ATOMIC, 279-MM, PRACTICE, SPOTTING, XM390, COMPOSITION B LOADED (C)

First Report on Ordnance Project No. TN2-8051

Dates of Test: December 1959 to April 1960

ABSTRACT (S)

Three Projectile, Atomic, 279-mm, Practice, Spotting, XM390, Composition B loaded were fragmented to evaluate fragmentation characteristics. The test results indicate that the projectile produced an average of 69,137 steel fragments with an average weight of 2.74 grains, and an average of 15,191 aluminum fragments with an average weight of 3.28 grains, with a mean velocity of 4876 feet per second. Seventy per cent of the steel fragments, and sixty-six per cent of the aluminum fragments were in the weight interval of 0 to 1 grain.

In view of the high percentage of small fragments (0 to 1 grain) produced by the pearlitic malleable iron warhead, further study should be conducted regarding the use of another explosive filler. Since the brisance of TNT is less than that of composition B, it is recommended that this warhead be tested using TNT as an explosive filler.

CONTENTS (U)

(The Annex is on file in the Technical Library, APG for reference purposes. Copies of the Annex may be furnished to recipients of this report upon request.)

1. (U) INTRODUCTION

The Feltman Research and Engineering Laboratories of Picatinny Arsenal requested that complete fragmentation data be obtained for the Projectile, Atomic, 279-mm, Practice, Spotting, XM390, incorporating warheads of pearlitic malleable iron that have undergone heat-treatment conditions to have a 50,000 psi minimum yield.

2. (S) DESCRIPTION OF MATERIEL

The Projectile, Atomic, 279-mm, Practice, Spotting, XM390, consists of the following components:

a. Body - A thin-walled shell, 14.84 inches long and varying from 11.03 inches to 4.70 inches in diameter by following a 100-inch radius curve, and machined from 75ST6 aluminum forging (DWG AA-44-931, Reference 1).

b. Antenna - A dummy antenna for training, aerodynamics, and moment-matching purposes; machined from steel bar stock C1010; 6.66 inches long and varying from 4.14 inches to 2.25 inches in diameter. The antenna also forms a part of the gas seal to keep propellent gases from entering the rear body (DWG AA-44-898, Reference 1).

c. Support, casing - Used to mount the HE warhead and consists of a ring 10.46 inches in diameter with a boss for transmission of set-back from the rear body. The support has eight mounting lugs which when mated with the lugs on the warhead transmit the warhead launching accelerations to the body (DWG AA-44-899, Reference 1).

d. Windshield - Fibrous glass mats for reinforcing plastics, and resin, low pressure, laminating, type I, specification MIL-R-7575 (DWG AA-44-897, Reference 1).

e. Warhead Assembly - A pearlitic malleable iron ball with 8.96-inch outside diameter and 8.11-inch inside diameter. The warheads were subjected to a heat-treatment process that gave a minimum yield of 50,000 psi. Each warhead was loaded with 16.33 pounds of composition B explosive (Ammunition Lot No. PA-E-30299; DWG AA-44-918, Reference 2).

The projectiles used for fragmentation testing were incomplete and did not include the fin, shroud, setting dial, option switch, and tactical fuze.

The following materiel was used in this test:

a. Three body assemblies for Projectile, Atomic, 279-mm, Practice, Spotting, XM390 for fragmentation tests only, ammunition Lot No. PA-E-30478.

b. Three pearlitic malleable iron warheads for projectile, M730, ammunition Lot No. PA-E-30299.

c. Three Fuzes, PD, M51A5, modified for static firing, no lot number.

d. Three Blasting Caps, Electric, Type II.

3. DETAILS OF TEST

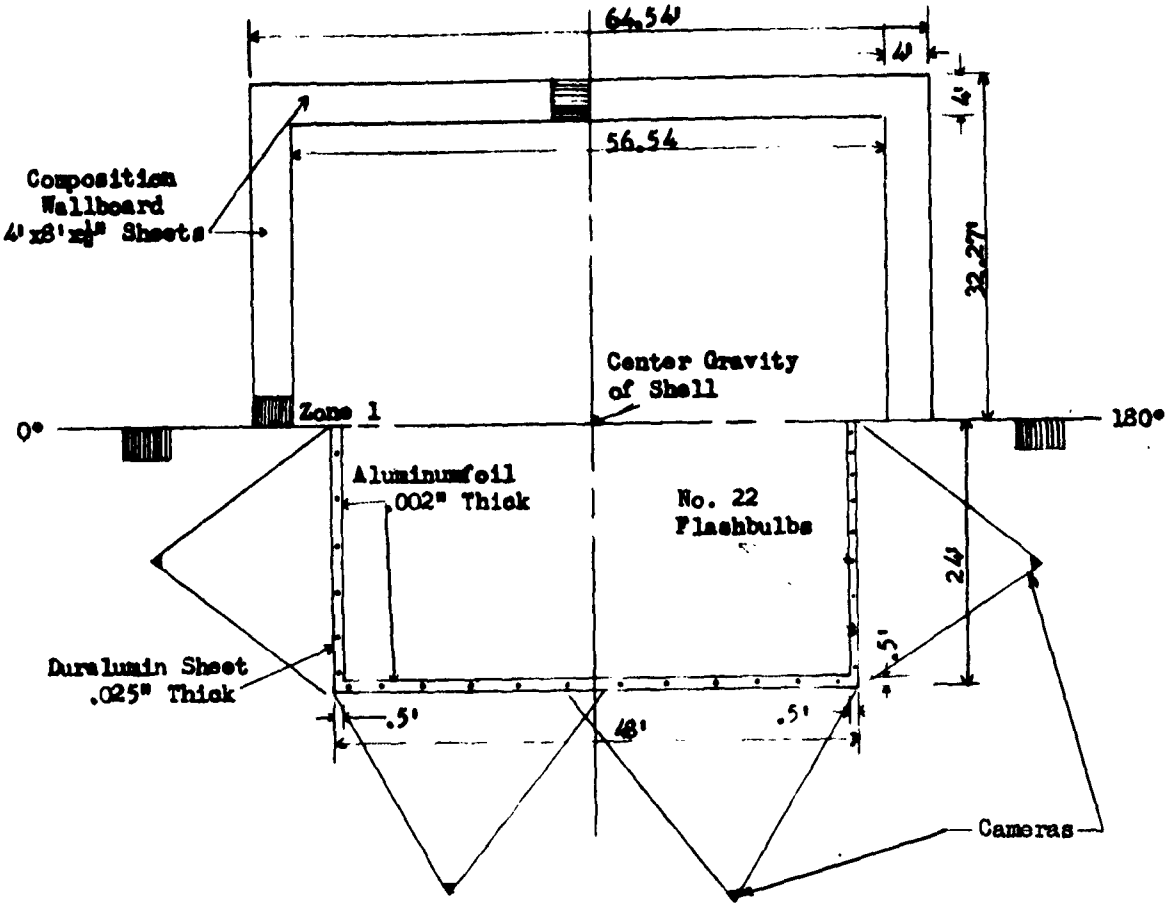
3.1 (U) Facilities

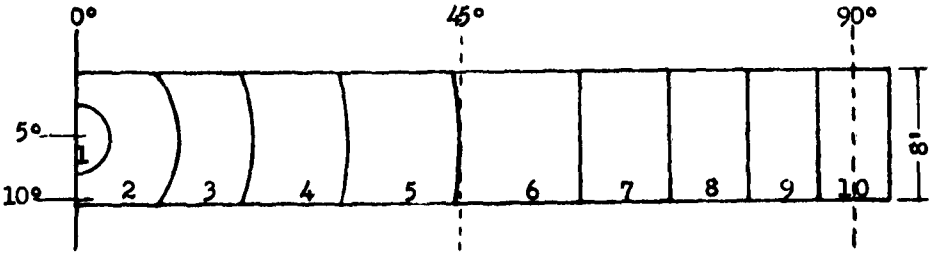
A rectangular arena arranged around the ammunition was used for the fragmentation test. The arena was divided into a recovery-surface area of 180° and a velocity-target area of 180°.

The fragment-recovery area consisted of a wooden structure containing 4- by 8-foot by 1/2-inch sheets of composition wallboard placed upright to a depth of 4 feet. This wallboard was gridded into 10° zones: annular zones from 0° to 45° and 135° to 180°; vertical zones from 45° to 135° (zone 1, 0° to 5°; zone 2, 5° to 15°; zone 3, 15° to 25° [illegible] Figure 1). The perpendicular distance from the center of gravity of the projectile to the composition wallboard at 0°, 90°, and 180° was 20.27 feet (see Figure 1). In addition, two boxes, 4 by 8 by 3 feet in depth, were filled with composition wallboard and placed outside of the test arena. One was placed at the nose end or 0°, and the other at the base end or 180°, both 35 feet from the center of the test setup. These recovery boxes were used to obtain additional data from the nose and base fragments. This was accomplished by subtending the arc of both zone 1 on the nose box and zone 19 on the base box, making it possible to recover a better sample of fragments that had penetrated the wallboard in these two zones. Figures 1, 2, and 3 show a plan view and photographs of a typical fragmentation test setup.

Two 180° vertical walls, 8 feet high and 6 inches apart, with vertical supports placed at 4-foot intervals, comprised the fragment-velocity setup. The outer wall contained 24 sheets of duralumin, each 4 by 8 feet by 0.020 inch thick with the outside surface painted black, and gridded into 2-foot horizontal sections and 19 zones vertically, corresponding with the zones gridded on the wallboard. Figures 4 and 5 show velocity target gridding. The perpendicular distance from the center of the ammunition to the duralumin at 0°, 90°, and 180° was 24 feet. The inner wall of the setup was composed of 0.002-inch aluminum foil used as a reflector for the number 22 flashbulbs which were placed at intervals between the walls (nine bulbs for each 4- by 8-foot target area). These flashbulbs were timed to reach their maximum brilliance when the fragments perforated the velocity targets. Flashbulbs were also placed around the outside of the arena to illuminate the velocity targets so that a record of the gridding would be visible on the high-speed film. The flashbulb function was synchronized by means of an electric sequence timer which assured that the outside bulbs would be out before the fragments struck the velocity targets.

PLAN VIEW OF TEST SETUP





ZONING OF RECOVERY AND VELOCITY TARGETS

Figure 1.

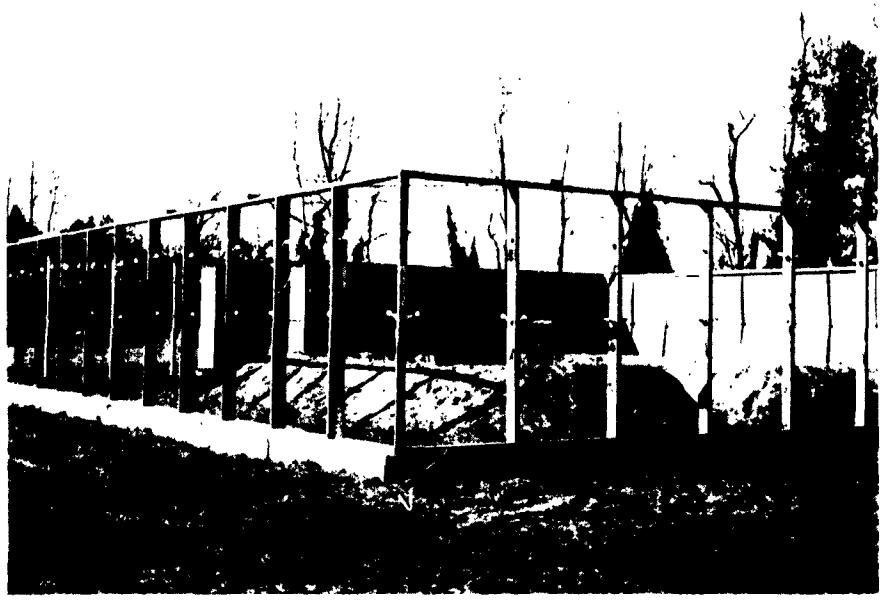


Figure 2 - S18-001-1385-7-1T/ORD-60: Typical View of Test Setup, Showing Zoning for Fragment Recovery.

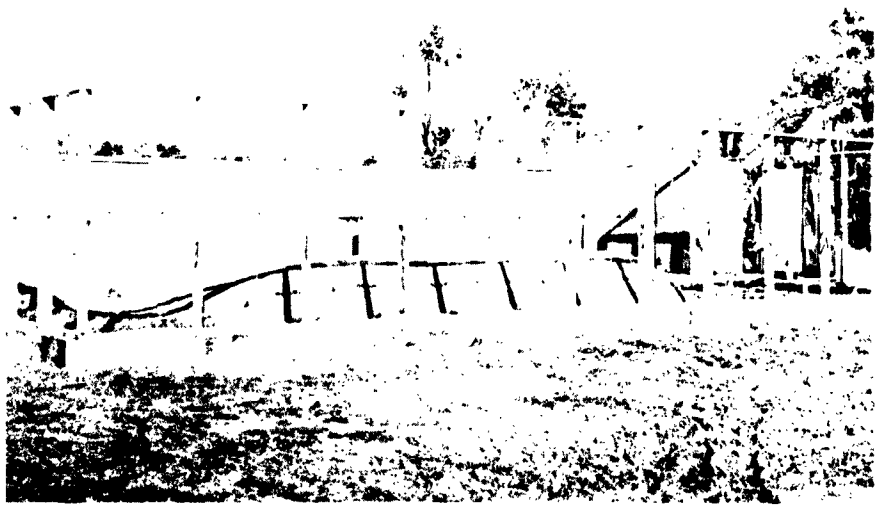


Figure 3 - S18-001-1385-7-2T/ORD-60: Typical View of Test Setup, Showing Various Stages of Completion.

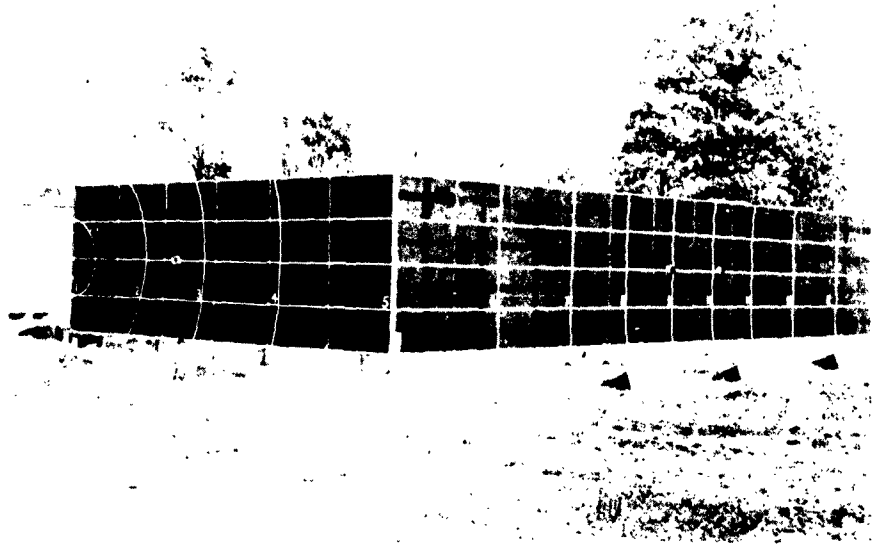


Figure 4 - S18-001-1385-7-4T/ORD-60: General View of Velocity Targets Showing Gridding.

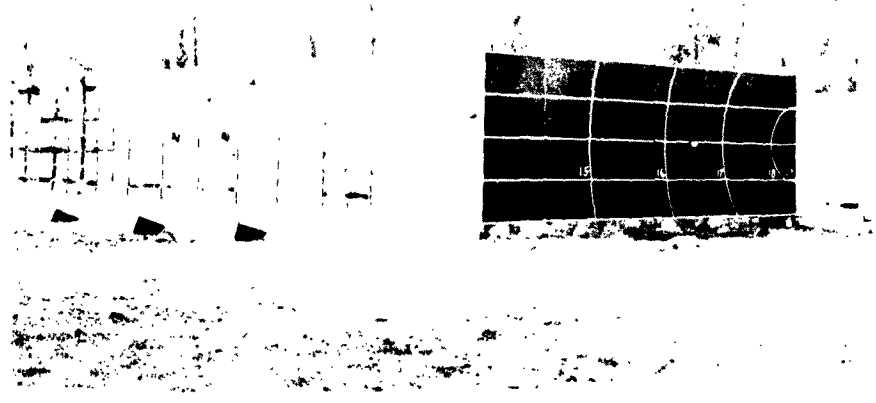


Figure 5 - S18-001-1385-7-3T/ORD-60: General View of Velocity Targets, Showing Gridding.

In order to obtain additional information on velocity levels of the steel and aluminum fragments, two recovery boxes, each 8 by 4 by 3 feet in depth, filled with composition wallboard and faced with a sheet of 0.020-inch duralumin painted black, were placed on top of the recovery setup, one at 45° and the other 135° from the nose of the projectile. These velocity-recovery boxes were used to correlate the recovered fragments with their respective velocities for Round 3 only. However, insufficient data were obtained to add any information regarding distribution (see Analytical Laboratory Report, Appendix B).

Four high-speed motion-picture cameras operating at a speed of approximately 10,000 frames per second and equipped with frequency standards and electronic timing devices were positioned around the targets to photograph both the detonation of the projectile and the impact of fragments on the velocity targets. To record the instant of detonation for zero time, the cameras were focused on the shell through the viewing holes in the velocity targets. Views of the flashbulb reflectors and cardboard cylinders in position are shown in Figures 4 and 5.

OPM 80-16, Volume IV contains further details of flashbulb installation and velocity measurement technique.

A richochet stop was provided for both the recovery area and the velocity targets to prevent fragments that struck the ground from ricocheting into the recovery or velocity panels. OPM 70-90, Volume I, contains other details on fragmentation procedure.

3.2 Procedure

(U) The projectile and component parts were weighed and the recorded weights are shown in Table I.

Table I (S). Projectile, Atomic, 279-mm, Practice, Spotting, XM390, Lot No. PA-E-30478

Round No.	Warhead No.	Weight Warhead Metal Parts, lb	Weight Antenna Assembly, lb[a]	Weight Fuze M51A5 (Mod), lb	Weight Explosive Composition B, lb	Weight Casing Support and Body lb[a]	Weight Windshield, lb[a]
1	PA-64-59	27.60	5.85	1.50	16.63	10.73	5.92
2	PA-65-59	27.53	5.85	1.52	16.47	10.73	5.92
3	PA-66-59	27.53	5.85	1.50	16.67	10.73	5.92

[a]Nominal weights, data supplied by Picatinny Arsenal (see correspondence, Appendix A).

(U) Each projectile was assembled with Fuze, PD, M51A5, modified for static firing, and placed individually on a wooden pedestal at the center of the setup. The pedestal was constructed so that the horizontal centerline of the projectile corresponded with the horizontal centerline of both the recovery boxes and velocity targets. The nose of each projectile pointed toward the

edges of the composition wallboard and velocity targets at 0°. The projectile was detonated by using a blasting cap, electric, type II initiated by a 110-volt power source.

(U) After detonation of each projectile, a plot of the position of each hit in the duralumin targets was recorded on graph paper and correlated with the image of hits obtained on the high-speed film. The individual fragment velocity was computed from the known distance of the shell to the target, and the known fragment travel time obtained from the high-speed film.

(U) The fragments that impacted in the wallboard were located by using an electronic metal detector. They were then recovered, identified as to zone, cleaned, weighed, separated according to type of metal (steel or aluminum), and segregated into weight intervals.

(U) A sample of the recovered fragments, identified by zone and weight groups, is shown in Figures 6 and 7.

(U) Tables II, III, and IV identify the fragments by zone number, weight, and type of metal for each weight interval.

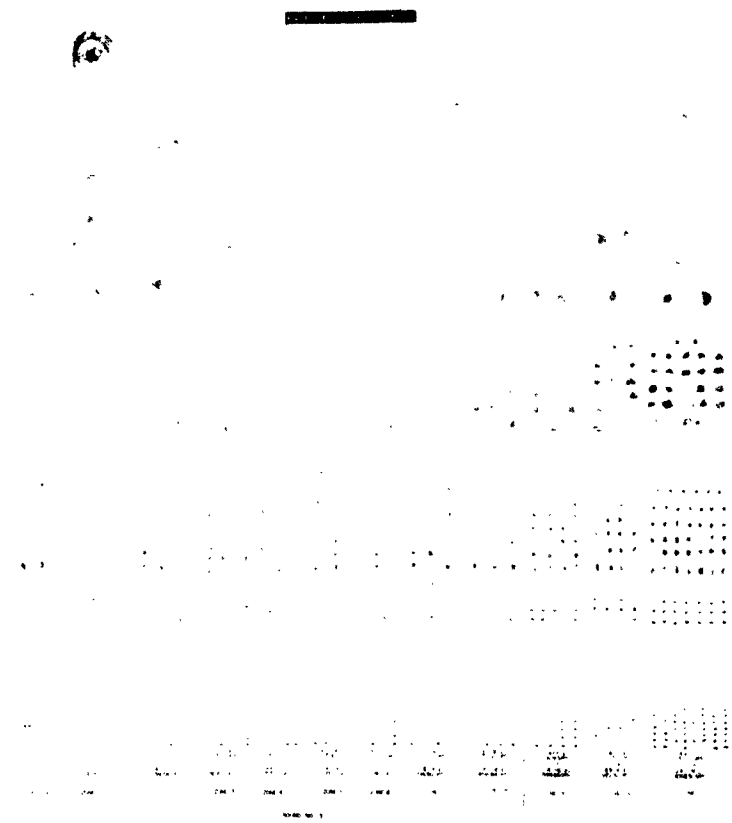


Figure 6 - S18-001-1385-7-6T/ORD-60 (S): Recovered Fragments of Projectile, 279-mm, XM390, Composition B Loaded, Zones 1 to 11.

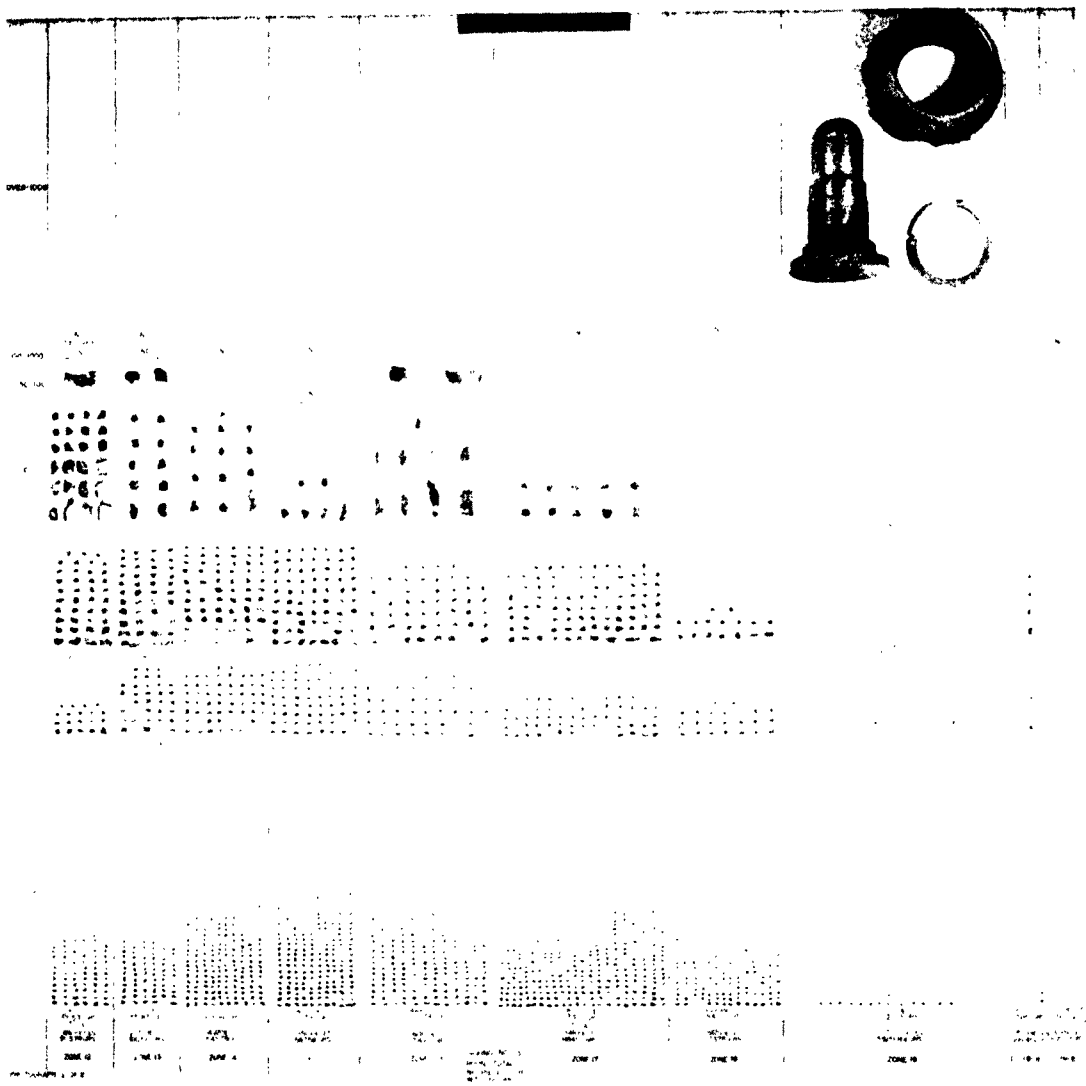


Figure 7 - S18-001-1385-7-5T/ORD-60 (S): Recovered Fragments of Projectile, 279-mm, XM390, Composition B Loaded, Zones 12 to 19.

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Table II (S). **FRAGMENT RECOVERY**

TYPE: 279-mm, XM389 **DATE FIRED:** 30 December 1959 **ROUND NO.:** 1

FILLER: Composition B

S FRAGMENTS FROM WARHEAD

WEIGHT INTERVALS IN GRAIN		DISTRIBUTION OF FRAGMENTS BY NUMBER AND WEIGHT										
		Zone 1	Zone 2	Zone 3	Zone 4	Zone 5	Zone 6	Zone 7	Zone 8	Zone 9	Zone 10	Zone 11
0 - 1	NO.	97	164	115	84	40	49	45	46	277	69	24
	WT.	22.69	47.45	30.50	19.67	10.42	15.06	9.63	13.35	35.40	18.13	7.04
1 - 2	NO.	14	26	15	7	9	1	2	7	45	9	4
	WT.	20.40	37.50	23.22	9.71	14.73	1.21	2.68	11.60	64.40	11.85	6.37
2 - 5	NO.	13	24	10	7	11	4	6	12	44	7	5
	WT.	38.00	81.97	37.00	17.34	36.00	12.95	20.21	36.80	146.40	20.62	17.80
5 - 8	NO.	4	7	5	4	6	7	2	5	11	3	4
	WT.	26.65	38.16	46.40	25.52	33.20	43.60	12.22	32.48	68.60	20.90	24.34
8 - 10	NO.	2	5	3	7	2	2	1	1	3		4
	WT.	18.60	44.27	26.72	61.74	17.13	17.72	8.92	8.60	25.30		35.60
10 - 15	NO.	1	6	6	5	5	3	3	1	7	1	3
	WT.	12.53	94.55	76.74	60.50	61.00	35.20	33.00	13.10	81.60	12.57	40.54
15 - 20	NO.		2	4	8	1	1	2		4	2	3
	WT.		32.14	70.00	132.38	17.62	19.75	32.24		65.30	31.00	46.20
20 - 25	NO.		4	2	4	4		2	1	3		1
	WT.		84.40	41.38	82.69	89.18		41.20	23.90	67.00		22.30
25 - 35	NO.	1	3	3	3		1	2	1	2	2	2
	WT.	33.30	93.20	80.51	75.25		26.68	54.00	34.40	64.00	59.62	54.10
35 - 50	NO.	2	4	3	1	1	3	1	3	2	1	
	WT.	79.62	172.28	135.42	35.04	40.00	122.32	39.18	109.20	91.62	43.80	
50 - 60	NO.	1	2	1	1	2	2	1				
	WT.	59.60	100.08	55.60	52.80	101.56	112.52	53.60				
60 - 70	NO.			1		1		1	1	1	1	
	WT.			65.40		66.00		63.20	61.00	61.20	68.20	
70 - 80	NO.									1		1
	WT.									75.72		78.20
80 - 90	NO.							1				
	WT.							85.00				
90 - 100	NO.								2	1		
	WT.								184.00	91.20		

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FRAGMENT RECOVERY

TYPE: 27?-mm. XM3?0 **DATE FIRED:** 30 December 1?5? **ROUND NO.:** 1

FILLER: Composition B

S FRAGMENTS FROM WARHEAD

WEIGHT INTERVALS IN GRAIN		DISTRIBUTION OF FRAGMENTS BY NUMBER AND WEIGHT										
		Zone 1	Zone 2	Zone 3	Zone 4	Zone 5	Zone 6	Zone 7	Zone 8	Zone 9	Zone 10	Zone 11
100 - 125	NO.		1						1			
	WT.		100.00						102.00			
125 - 150	NO.		1						1			
	WT.		120.00						137.00			
150 - 200	NO.								1			1
	WT.								172.00			156.00
200 - 250	NO.											
	WT.											
250 - 300	NO.											
	WT.											
300 - 400	NO.											
	WT.											
400 - 500	NO.											
	WT.											
500 - 750	NO.											
	WT.											
750 - 1000	NO.		1									
	WT.		740.00									
1000and Over	NO.	1										
	WT.	5043.00										
	NO.											
	WT.											
	NO.											
	WT.											
	NO.											
	WT.											
	NO.											
	WT.											
Total	NO.	136	252	171	131	62	73	61	63	401	95	52
	WT.	5354.00	1044.00	690.33	576.04	491.91	407.01	455.08	939.43	936.24	266.77	436.43

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FRAGMENT RECOVERY

TYPE: 279-mm, XM390 **DATE FIRED:** 30 December 1959 **ROUND NO.:** 1

FILLER: Composition B

S FRAGMENTS FROM WARHEAD

WEIGHT INTERVALS IN GRAIN	DISTRIBUTION OF FRAGMENTS BY NUMBER AND WEIGHT											
		Zone 12	Zone 13	Zone 14	Zone 15	Zone 16	Zone 17	Zone 18	Zone 19		Total No.	Total Weight
0 - 1	NO.	54	92	114	378	594	895	770	168		4065	
	WT.	19.77	25.96	31.64	99.70	112.60	121.30	94.40	37.44			322.75
1 - 2	NO.	8	16	29	36	52	26	15	10		331	
	WT.	13.35	24.95	41.40	50.30	71.00	37.40	20.63	13.23			476.36
2 - 5	NO.	12	19	31	39	45	23	6	6		324	
	WT.	34.69	59.30	93.40	122.60	140.00	71.84	13.02	15.63			1016.13
5 - 8	NO.	7	3	14	10	6	11	2			114	
	WT.	44.39	19.55	86.00	56.20	37.04	72.84	12.53				706.12
8 - 10	NO.	1		8	1	1	5				46	
	WT.	8.35		68.00	9.23	9.46	45.20					404.89
10 - 15	NO.	5	3	4	4	4	6				69	
	WT.	60.34	33.40	45.12	50.30	48.36	66.70					828.95
15 - 20	NO.	2	2	3		1	1				39	
	WT.	36.24	33.30	53.40		15.13	15.35					654.13
20 - 25	NO.	2					3				26	
	WT.	46.30					68.30					567.65
25 - 35	NO.	4	2	1		2					29	
	WT.	114.40	53.30	27.18		65.60						339.54
35 - 50	NO.	1	1								23	
	WT.	41.44	41.40									351.32
50 - 60	NO.	1									11	
	WT.	53.84										589.62
60 - 70	NO.										6	
	WT.											385.00
70 - 80	NO.						1				3	
	WT.						79.00					232.92
80 - 90	NO.										1	
	WT.											85.00
90 - 100	NO.										3	
	WT.											275.20

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FRAGMENT RECOVERY

TYPE: 279-mm, XM390 **DATE FIRED:** 30 December 1952 **ROUND NO.:** 1

FILLER: Composition B

S FRAGMENTS FROM WARHEAD

WEIGHT INTERVALS IN GRAIN		DISTRIBUTION OF FRAGMENTS BY NUMBER AND WEIGHT										
		Zone 12	Zone 13	Zone 14	Zone 15	Zone 16	Zone 17	Zone 18	Zone 19		Total No.	Total Weight
100 - 125	NO.										2	
	WT.											202.00
125 - 150	NO.						1				3	
	WT.						141.72					406.72
150 - 200	NO.										2	
	WT.											325.00
200 - 250	NO.											
	WT.											
250 - 300	NO.											
	WT.											
300 - 400	NO.											
	WT.											
400 - 500	NO.											
	WT.											
500 - 750	NO.											
	WT.											
750 - 1000	NO.										1	
	WT.											730.00
1000 and Over	NO.								1		2	
	WT.								30500.00			43543.00
	NO.											
	WT.											
	NO.											
	WT.											
	NO.											
	WT.											
	NO.											
	WT.											
Total	NO.	100	138	204	460	635	972	743	135		5100	
	WT.	524.64	292.66	446.14	359.33	499.74	723.75	140.53	30566.36			54105.95

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SECRET

FRAGMENT RECOVERY

TYPE: 279-mm, XM390 **DATE FIRED:** 30 December 1959 **ROUND NO.:** 1

FILLER: Composition B

FRAGMENTS FROM OUTER CASE (ALUMINUM)

WEIGHT INTERVALS IN GRAIN	DISTRIBUTION OF FRAGMENTS BY NUMBER AND WEIGHT											
			Zone 9	Zone 10	Zone 11	Zone 12	Zone 13	Zone 14	Zone 15	Zone 16	Zone 17	Zone 18
0 - 1	NO.		6	11	13	15	32	34	96	152	158	79
	WT.	No	2.89	3.84	4.12	5.09	7.28	13.70	34.80	42.20	23.72	14.90
1 - 2	NO.	Recovery	5	7	1	5	5	2	11	11	2	3
	WT.		6.50	10.19	1.27	7.20	6.92	2.66	16.42	16.15	2.90	3.88
2 - 5	NO.	in Zones	2	2	5	2	6	3	12	11	6	1
	WT.	1	7.85	7.02	19.35	6.15	20.77	8.65	38.80	36.60	20.17	2.38
5 - 8	NO.	2		3	3	3	5	2	5	4		2
	WT.	3		16.05	20.95	19.92	33.00	12.45	30.40	24.43		11.86
8 - 10	NO.	4	1	2	1	4		3		1	1	
	WT.	5	8.27	18.30	9.05	35.00		27.02		8.52	9.26	
10 - 15	NO.	6		3		1	2	1	2	3		
	WT.	7		36.60		10.02	21.80	13.61	25.40	35.00		
15 - 20	NO.	8		2		1	2		1			1
	WT.			31.60		16.32	36.00		19.37			15.65
20 - 25	NO.			2	4				3			
	WT.			43.08	88.80				72.66			
25 - 35	NO.			1	2	2	1		1	3		
	WT.			29.80	57.00	56.60	25.55		25.94	94.54		
35 - 50	NO.			2	2	4				3	1	
	WT.			83.18	88.00	149.64				136.40	38.64	
50 - 60	NO.									1		
	WT.									51.80		
60 - 70	NO.			1								
	WT.			67.82								
70 - 80	NO.			1								
	WT.			77.58								
80 - 90	NO.											
	WT.											
90 - 100	NO.		1			1						
	WT.		90.76			90.72						

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FRAGMENT RECOVERY

TYPE: 279-mm, XM390 **DATE FIRED:** 30 December 1959 **ROUND NO.:** 1

FILLER: Composition B

FRAGMENTS FROM OUTER CASE (ALUMINUM)

WEIGHT INTERVALS IN GRAIN		DISTRIBUTION OF FRAGMENTS BY NUMBER AND WEIGHT										
			Zone 9	Zone 10	Zone 11	Zone 12	Zone 13	Zone 14	Zone 15	Zone 16	Zone 17	Zone 18
100 - 125	NO.	No										
	WT.											
125 - 150	NO.	Recovery										
	WT.											
150 - 200	NO.	in										
	WT.											
200 - 250	NO.	Zones										
	WT.	1										
250 - 300	NO.	2										
	WT.	3										
300 - 400	NO.	4										
	WT.	5										
400 - 500	NO.	6										
	WT.	7										
500 - 750	NO.	8										
	WT.											
750 - 1000	NO.											
	WT.											
1000 and Over	NO.											
	WT.											
	NO.											
	WT.											
	NO.											
	WT.											
	NO.											
	WT.											
	NO.											
	WT.											
Total	NO.		15	37	31	38	53	45	131	189	168	86
	WT.		116.27	425.06	288.54	396.66	151.32	78.09	263.79	445.64	94.69	48.67

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FRAGMENT RECOVERY

TYPE: 279-mm, XM390 **DATE FIRED:** 30 December 1959 **ROUND NO.:** 1

FILLER: Composition B

A FRAGMENTS FROM OUTER CASE (ALUMINUM)

WEIGHT INTERVALS IN GRAIN		DISTRIBUTION OF FRAGMENTS BY NUMBER AND WEIGHTS									Total No.	Total Weight
		Zone 19										
0 - 1	NO.	11									607	
	WT.	2.36										154.90
1 - 2	NO.	1									53	
	WT.	1.49										75.58
2 - 5	NO.	4									54	
	WT.	11.75										179.49
5 - 8	NO.										27	
	WT.											169.06
8 - 10	NO.										13	
	WT.											115.42
10 - 15	NO.										12	
	WT.											142.43
15 - 20	NO.										7	
	WT.											118.94
20 - 25	NO.										9	
	WT.											204.54
25 - 35	NO.										10	
	WT.											289.43
35 - 50	NO.										12	
	WT.											495.86
50 - 60	NO.										1	
	WT.											51.80
60 - 70	NO.										1	
	WT.											67.82
70 - 80	NO.										1	
	WT.											77.58
80 - 90	NO.											
	WT.											
90 - 100	NO.										2	
	WT.											181.48

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FRAGMENT RECOVERY

TYPE: 279-mm, XM390 **DATE FIRED:** 30 December 1959 **ROUND NO.:** 1

FILLER: Composition B

FRAGMENTS FROM OUTER CASE (ALUMINUM)

WEIGHT INTERVALS IN GRAIN		DISTRIBUTION OF FRAGMENTS BY NUMBER AND WEIGHTS										
		Zone 19									Total No.	Total Weight
100 - 125	NO.											
	WT.											
125 - 150	NO.											
	WT.											
150 - 200	NO.											
	WT.											
200 - 250	NO.											
	WT.											
250 - 300	NO.											
	WT.											
300 - 400	NO.											
	WT.											
400 - 500	NO.											
	WT.											
500 - 750	NO.											
	WT.											
750 - 1000	NO.											
	WT.											
1000 and Over	NO.	1									1	
	WT.	18900.00										18900.00
	NO.											
	WT.											
	NO.											
	WT.											
	NO.											
	WT.											
	NO.											
	WT.											
Total	NO.	17									810	
	WT.	18915.60										21224.33

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SECRET

FRAGMENT RECOVERY

TYPE: 279-mm, XM390 **DATE FIRED:** 30 December 1959 **ROUND NO.:** 1

FILLER: Composition B

FRAGMENTS FROM WARHEAD RECOVERED FROM NOSE AND BASE BOXES

WEIGHT INTERVALS IN GRAIN		DISTRIBUTION OF FRAGMENTS BY NUMBER AND WEIGHTS							Total A Frags	Total S and F Frags		Grand Total All Frags
		Zone 1N	Zone 2N	Total	Zone 18B	Zone 19B	Total					
0 - 1	NO.	18	77	95	57	31	88		607	4065		4855
	WT.	9.18	29.20	38.38	20.96	12.00	32.96		154.90	822.75		1048.99
1 - 2	NO.	6	14	20	6	16	22		53	331		426
	WT.	8.82	21.55	30.37	7.49	23.02	30.51		75.58	476.96		613.42
2 - 5	NO.	8	11	19	3	3	6		54	324		403
	WT.	23.90	33.04	56.94	9.42	8.41	17.83		179.49	1016.13		1270.39
5 - 8	NO.	1	4	5					27	114		146
	WT.	6.60	24.83	31.43					169.06	706.12		906.61
8 - 10	NO.	2	1	3					13	46		62
	WT.	16.67	8.32	24.99					115.42	404.89		545.30
10 - 15	NO.	4	2	6					12	69		87
	WT.	52.00	23.09	75.09					142.43	828.95		1046.47
15 - 20	NO.								7	39		46
	WT.								118.94	654.18		773.12
20 - 25	NO.								9	26		35
	WT.								204.54	567.65		772.19
25 - 35	NO.								10	29		39
	WT.								289.43	839.54		1128.97
35 - 50	NO.								12	23		35
	WT.								495.86	951.32		1447.18
50 - 60	NO.								1	11		12
	WT.								51.80	589.62		641.42
60 - 70	NO.								1	6		7
	WT.								67.82	385.00		452.82
70 - 80	NO.		1	1					1	3		4
	WT.		79.80	79.80					77.58	232.92		310.50
80 - 90	NO.									1		1
	WT.									85.00		85.00
90 - 100	NO.		1	1					2	3		5
	WT.		99.00	99.00					181.48	275.20		456.68

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FRAGMENT RECOVERY

TYPE: 279-mm, XM390 **DATE FIRED:** 30 December 1959 **ROUND NO.:** 1

FILLER: Composition B

S FRAGMENTS RECOVERED FROM NOSE AND BASE BOXES, (NOSE - FUZE) (BASE - STEEL)

WEIGHT INTERVALS IN GRAIN	DISTRIBUTION OF FRAGMENTS BY NUMBER AND WEIGHTS											
		Zone 1N	Zone 2N	Total	Zone 18B	Zone 19B	Total		Total A Frags	Total S and F Frags		Grand Total All Frags
100 - 125	NO.									2		2
	WT.									202.00		202.00
125 - 150	NO.									3		3
	WT.									406.72		406.72
150 - 200	NO.									2		2
	WT.									328.00		328.00
200 - 250	NO.											
	WT.											
250 - 300	NO.											
	WT.											
300 - 400	NO.											
	WT.											
400 - 500	NO.											
	WT.											
500 - 750	NO.											
	WT.											
750 - 1000	NO.									1		1
	WT.									790.00		790.00
1000 and Over	NO.								1	2		3
	WT.								18900.00	43543.00		62443.00
	NO.											
	WT.											
	NO.											
	WT.											
	NO.											
	WT.											
	NO.											
	WT.											
Total	NO.	39	111	150	66	50	116		810	5100		6176
	WT.	117.17	318.83	436.00	37.87	43.43	81.30		21224.33	54105.95		75847.58

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Table III (S). **FRAGMENT RECOVERY**

TYPE: 279-mm, XM390 **DATE FIRED:** 12 January 1960 **ROUND NO.:** 2

FILLER: Composition B

S FRAGMENTS FROM WARHEAD

WEIGHT INTERVALS IN GRAIN		DISTRIBUTION OF FRAGMENTS BY NUMBER AND WEIGHTS										
		Zone 1	Zone 2	Zone 3	Zone 4	Zone 5	Zone 6	Zone 7	Zone 8	Zone 9	Zone 10	Zone 11
0 - 1	NO.	90	120	91	100	49	23	42	20	139	47	35
	WT.	27.04	30.55	23.55	17.59	5.50	7.95	14.94	7.65	42.90	14.45	12.73
1 - 2	NO.	10	16	14	17	7	6	7	5	27	8	18
	WT.	13.14	23.27	21.50	22.84	10.41	8.96	11.06	7.09	39.20	11.27	27.65
2 - 5	NO.	15	19	11	13	9	6	12	6	19	8	16
	WT.	44.64	61.85	40.20	47.02	28.22	18.40	37.30	17.44	62.88	26.07	58.34
5 - 8	NO.	4	6	7	8	3	4	7	3	9	5	8
	WT.	24.81	37.97	42.44	52.46	21.36	28.46	41.26	17.69	57.80	32.00	51.80
8 - 10	NO.		3	6	8	2		3	2	4	2	3
	WT.		26.14	54.17	73.85	17.94		28.67	17.44	36.30	17.64	25.08
10 - 15	NO.	6	3	4	10	5	3	2		7	4	5
	WT.	74.48	32.88	45.20	119.00	57.88	39.40	25.29		84.00	52.00	55.52
15 - 20	NO.	1	4	2	8		1		2	4	5	2
	WT.	19.40	75.83	38.57	143.80		15.52		33.00	68.44	83.24	32.44
20 - 25	NO.			3		3	2	2		3	1	2
	WT.			68.44		66.70	40.64	46.46		73.26	24.75	46.60
25 - 35	NO.		3	5	2	2	2	1	1	5		2
	WT.		90.09	141.82	62.68	52.60	61.62	33.68	25.40	147.80		63.20
35 - 50	NO.		2	3	2	2		4		1		1
	WT.		80.03	130.60	77.80	87.00		163.00		46.08		35.70
50 - 60	NO.	1	2	3				2		1		
	WT.	50.60	109.60	161.00				105.80		52.00		
60 - 70	NO.						2	1			2	
	WT.						126.50	60.26			137.84	
70 - 80	NO.					1	1		1		1	1
	WT.					70.24	75.10		74.20		71.24	70.03
80 - 90	NO.						1	1				
	WT.						85.20	82.00				
90 - 100	NO.									1		
	WT.									94.12		

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FRAGMENT RECOVERY

TYPE: 279-mm, XM390 **DATE FIRED:** 12 January 1960 **ROUND NO.:** 2

FILLER: Composition B

S FRAGMENTS FROM WARHEAD

WEIGHT INTERVALS IN GRAIN		DISTRIBUTION OF FRAGMENTS BY NUMBER AND WEIGHTS										
		Zone 1	Zone 2	Zone 3	Zone 4	Zone 5	Zone 6	Zone 7	Zone 8	Zone 9	Zone 10	Zone 11
100 - 125	NO.		1						1			
	WT.		112.20						115.00			
125 - 150	NO.											
	WT.											
150 - 200	NO.											
	WT.											
200 - 250	NO.		1							1		
	WT.		202.00							209.00		
250 - 300	NO.											
	WT.											
300 - 400	NO.	1										
	WT.	384.00										
400 - 500	NO.		1									
	WT.		446.00									
500 - 750	NO.		1									
	WT.		703.00									
750 - 1000	NO.											
	WT.											
1000 and Over	NO.	1										
	WT.	4941.00										
	NO.											
	WT.											
	NO.											
	WT.											
	NO.											
	WT.											
	NO.											
	WT.											
Total	NO.	129	182	149	168	83	51	84	41	221	83	93
	WT.	5579.11	2031.41	767.49	617.04	417.85	507.75	649.78	314.91	1013.78	470.50	479.14

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FRAGMENT RECOVERY

TYPE: 279-mm, XM390 DATE FIRED: 12 January 1960 ROUND NO.: 2

FILLER: Composition B

S FRAGMENTS FROM WARHEAD

WEIGHT INTERVALS IN GRAIN		DISTRIBUTION OF FRAGMENTS BY NUMBER AND WEIGHTS									Total No.	Total Weight
		Zone 12	Zone 13	Zone 14	Zone 15	Zone 16	Zone 17	Zone 18	Zone 19			
0 - 1	NO.	64	118	97	311	322	490	532	123		2813	
	WT.	13.37	24.60	32.72	74.30	29.80	114.00	81.60	20.80			596.04
1 - 2	NO.	9	17	31	52	33	55	9	5		346	
	WT.	13.50	25.02	45.34	73.40	46.40	77.10	12.56	6.89			496.60
2 - 5	NO.	12	19	35	42	31	42	4	4		323	
	WT.	39.60	68.40	113.20	130.06	95.70	134.82	13.60	11.13			1048.87
5 - 8	NO.	9	13	10	11	10	15				132	
	WT.	56.20	80.06	67.00	69.60	61.50	91.28					833.69
8 - 10	NO.	1	5	6	1	5	6				57	
	WT.	8.20	46.12	51.20	9.94	43.00	52.60					508.29
10 - 15	NO.	3	7	5			4				68	
	WT.	32.20	78.40	63.00			48.00					807.25
15 - 20	NO.	2	2	2		1					36	
	WT.	33.84	33.26	35.20		19.80						632.34
20 - 25	NO.	2	1	1			2				22	
	WT.	44.40	21.60	20.22			43.34					496.41
25 - 35	NO.	1					2				26	
	WT.	27.20					56.00					762.09
35 - 50	NO.			1							16	
	WT.			38.44								658.65
50 - 60	NO.										9	
	WT.											479.06
60 - 70	NO.	1									6	
	WT.	64.80										389.40
70 - 80	NO.						1				6	
	WT.						73.80					434.66
80 - 90	NO.										2	
	WT.											167.20
90 - 100	NO.										1	
	WT.											94.12

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FRAGMENT RECOVERY

TYPE: 279-mm, XM390 DATE FIRED: 12 January 1960 ROUND NO.: 2

FILLER: Composition B

S FRAGMENTS FROM WARHEAD

WEIGHT INTERVALS IN GRAIN		DISTRIBUTION OF FRAGMENTS BY NUMBER AND WEIGHTS										
		Zone 12	Zone 13	Zone 14	Zone 15	Zone 16	Zone 17	Zone 18	Zone 19		Total No.	Total Weight
100 - 125	NO.										2	
	WT.											227.20
125 - 150	NO.											
	WT.											
150 - 200	NO.											
	WT.											
200 - 250	NO.										2	
	WT.											411.00
250 - 300	NO.											
	WT.											
300 - 400	NO.										1	
	WT.											384.00
400 - 500	NO.										1	
	WT.											446.00
500 - 750	NO.								1		2	
	WT.								510.00			1213.00
750 - 1000	NO.											
	WT.											
1000 and Over	NO.								1		2	
	WT.								38500.00			19441.00
	NO.											
	WT.											
	NO.											
	WT.											
	NO.											
	WT.											
	NO.											
	WT.											
Total	NO.	104	182	188	417	402	617	545	134		3873	
	WT.	333.31	377.46	466.32	357.30	296.20	690.94	107.76	3904.82			5426.97

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FRAGMENT RECOVERY

TYPE: 279-mm, XM390 DATE FIRED: 12 January 1960 ROUND NO.: 2

FILLER: Composition B

A FRAGMENTS FROM OUTER CASE (ALUMINUM)

WEIGHT INTERVALS IN GRAIN		DISTRIBUTION OF FRAGMENTS BY NUMBER AND WEIGHTS										
		Zone 1	Zone 2	Zone 3	Zone 4	Zone 5	Zone 6	Zone 7	Zone 8	Zone 9	Zone 10	Zone 11
0 - 1	NO.										7	24
	WT.	No	No	No	No	No	No	No	No		2.37	5.54
1 - 2	NO.									4	2	6
	WT.	Recovery	Recovery	Recovery	Recovery	Recovery	Recovery	Recovery	Recovery	6.16	3.15	8.39
2 - 5	NO.											10
	WT.											32.84
5 - 8	NO.										1	3
	WT.										7.10	18.80
8 - 10	NO.											3
	WT.											26.25
10 - 15	NO.										2	3
	WT.										27.60	35.46
15 - 20	NO.											2
	WT.											32.40
20 - 25	NO.											1
	WT.											24.07
25 - 35	NO.										1	1
	WT.										31.40	25.06
35 - 50	NO.											
	WT.											
50 - 60	NO.											
	WT.											
60 - 70	NO.											1
	WT.											68.24
70 - 80	NO.											1
	WT.											73.00
80 - 90	NO.											
	WT.											
90 - 100	NO.											
	WT.											

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FRAGMENT RECOVERY

TYPE: 279-mm, XM390 **DATE FIRED:** 12 January 1960 **ROUND NO.:** 2

FILLER: Composition B

A FRAGMENTS FROM OUTER CASE (ALUMINUM)

WEIGHT INTERVALS IN GRAIN		DISTRIBUTION OF FRAGMENTS BY NUMBER AND WEIGHTS										
		Zone 1	Zone 2	Zone 3	Zone 4	Zone 5	Zone 6	Zone 7	Zone 8	Zone 9	Zone 10	Zone 11
100 - 125	NO.											
	WT.											
125 - 150	NO.											
	WT.											
150 - 200	NO.											
	WT.											
200 - 250	NO.											
	WT.											
250 - 300	NO.											
	WT.											
300 - 400	NO.											
	WT.											
400 - 500	NO.											
	WT.											
500 - 750	NO.											
	WT.											
750 - 1000	NO.											
	WT.											
1000 and Over	NO.											
	WT.											
	NO.											
	WT.											
	NO.											
	WT.											
	NO.											
	WT.											
	NO.											
	WT.											
Total	NO.	-	-	-	-	-	-	-	-	4	13	55
	WT.	-	-	-	-	-	-	-	-	6.16	71.62	350.05

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FRAGMENT RECOVERY

TYPE: 279-mm, XM390 **DATE FIRED:** 12 January 1960 **ROUND NO.:** 2

FILLER: Composition B

A FRAGMENTS FROM OUTER CASE (ALUMINUM)

WEIGHT INTERVALS IN GRAIN		DISTRIBUTION OF FRAGMENTS BY NUMBER AND WEIGHTS									Total No.	Total Weight
		Zone 12	Zone 13	Zone 14	Zone 15	Zone 16	Zone 17	Zone 18	Zone 19			
0 - 1	NO.	48	25	14	88	124	75	73	15		493	
	WT.	17.17	11.14	7.56	26.85	37.44	20.06	12.29	5.79			148.21
1 - 2	NO.	1	10	9	14	10	4	1	1		62	
	WT.	1.90	12.94	12.32	18.28	13.29	5.64	1.79	1.94			85.80
2 - 5	NO.	6	9	10	12	16	6	2			71	
	WT.	22.17	32.28	32.30	39.26	51.66	20.53	5.79				236.83
5 - 8	NO.	5	6	2	2		2	1			22	
	WT.	33.20	36.20	11.57	13.67		12.37	6.70				139.61
8 - 10	NO.	3	1	1		2	2				12	
	WT.	27.60	8.52	9.83		16.80	19.00					108.00
10 - 15	NO.	3	2				2	2			14	
	WT.	38.24	22.51				24.50	20.96				169.27
15 - 20	NO.	3				2	1	1			9	
	WT.	49.64				33.00	17.57	17.60				150.21
20 - 25	NO.	4				1	1				7	
	WT.	90.42				24.52	20.00					159.01
25 - 35	NO.	8				1					11	
	WT.	230.00				33.28						319.74
35 - 50	NO.	2				1					3	
	WT.	80.40				37.32						117.72
50 - 60	NO.	1					1				2	
	WT.	52.20					50.60					102.80
60 - 70	NO.										1	
	WT.											68.24
70 - 80	NO.										1	
	WT.											73.00
80 - 90	NO.											
	WT.											
90 - 100	NO.											
	WT.											

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FRAGMENT RECOVERY

TYPE: 279-mm, XM390 **DATE FIRED:** 12 January 1960 **ROUND NO.:** 2

FILLER: Composition B

A FRAGMENTS FROM OUTER CASE (ALUMINUM)

WEIGHT INTERVALS IN GRAIN		DISTRIBUTION OF FRAGMENTS BY NUMBER AND WEIGHTS										
		Zone 12	Zone 13	Zone 14	Zone 15	Zone 16	Zone 17	Zone 18	Zone 19		Total No.	Total Weight
100 - 125	NO.											
	WT.											
125 - 150	NO.											
	WT.											
150 - 200	NO.											
	WT.											
200 - 250	NO.											
	WT.											
250 - 300	NO.											
	WT.											
300 - 400	NO.											
	WT.											
400 - 500	NO.											
	WT.											
500 - 750	NO.											
	WT.											
750 - 1000	NO.											
	WT.											
1000 and Over	NO.								1			1
	WT.								18760.00			18760.00
	NO.											
	WT.											
	NO.											
	WT.											
	NO.											
	WT.											
	NO.											
	WT.											
Total	NO.	84	53	36	116	157	94	80	17		709	
	WT.	642.94	123.59	73.58	100.06	247.31	190.27	65.13	18767.73			20638.44

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FRAGMENT RECOVERY

TYPE: 279-mm, XM390 DATE FIRED: 12 January 1960 ROUND NO.: 2

FILLER: Composition B

FRAGMENTS OF PROJECTILE RECOVERED FROM NOSE AND BASE

WEIGHT INTERVALS IN GRAIN	DISTRIBUTION OF FRAGMENTS BY NUMBER AND WEIGHTS											
		Zone 1N	Zone 2N	Total	Zone 18B	Zone 19B	Total		Total A Frags	Total S and F Frags		Grand Total of Frags
0 - 1	NO.	32	26	58	27	30	57		493	2813		3421
	WT.	10.52	9.76	20.28	12.96	15.14	28.10		148.21	596.04		792.63
1 - 2	NO.	8	9	17	11	3	14		62	346		439
	WT.	13.60	13.03	26.63	15.86	4.45	20.31		85.80	496.60		629.34
2 - 5	NO.	7	5	12	5		5		71	323		411
	WT.	22.65	15.03	37.68	14.70		14.70		236.83	1048.87		1338.08
5 - 8	NO.	1	2	3					22	132		157
	WT.	6.34	12.67	19.01					139.61	833.69		992.31
8 - 10	NO.	2	1	3					12	57		72
	WT.	17.62	8.20	25.82					108.00	508.29		642.11
10 - 15	NO.	1	1	2					14	68		84
	WT.	11.96	10.67	22.63					169.27	807.25		999.15
15 - 20	NO.		1	1					9	36		46
	WT.		18.50	18.50					150.21	632.34		801.05
20 - 25	NO.		1	1					7	22		30
	WT.		23.80	23.80					159.01	496.41		679.22
25 - 35	NO.								11	26		37
	WT.								319.74	762.09		1081.83
35 - 50	NO.								3	16		19
	WT.								117.72	658.65		776.37
50 - 60	NO.								2	9		11
	WT.								102.80	479.06		581.86
60 - 70	NO.								1	6		7
	WT.								68.24	389.40		457.64
70 - 80	NO.								1	6		7
	WT.								73.00	434.66		507.66
80 - 90	NO.									2		2
	WT.									167.20		167.20
90 - 100	NO.	1		1						1		2
	WT.	91.80		91.80						94.12		185.92

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FRAGMENT RECOVERY

TYPE: 279-mm, XM390 DATE FIRED: 12 January 1960 ROUND NO.: 2

FILLER: Composition B

FRAGMENTS OF PROJECTILE RECOVERED FROM NOSE AND BASE

WEIGHT INTERVALS IN GRAIN		DISTRIBUTION OF FRAGMENTS BY NUMBER AND WEIGHTS										
		Zone 1N	Zone 2N	Total	Zone 18B	Zone 19B	Total		Total A Frags	Total S and F Frags		Grand Total of Frags
100 - 125	NO.									2		2
	WT.									227.20		227.20
125 - 150	NO.											
	WT.											
150 - 200	NO.											
	WT.											
200 - 250	NO.									2		2
	WT.									411.00		411.00
250 - 300	NO.											
	WT.											
300 - 400	NO.									1		1
	WT.									384.00		384.00
400 - 500	NO.									1		1
	WT.									446.00		446.00
500 - 750	NO.									2		2
	WT.									1213.00		1213.00
750 - 1000	NO.											
	WT.											
1000 and Over	NO.								1	2		3
	WT.								18760.00	43441.00		62201.00
	NO.											
	WT.											
	NO.											
	WT.											
	NO.											
	WT.											
	NO.											
	WT.											
Total	NO.	52	46	98	43	33	76		709	3873		4756
	WT.	174.49	111.66	286.15	43.52	19.59	63.11		20638.44	54526.87		75514.57

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SECRET

Table IV (S). **FRAGMENT RECOVERY**

TYPE: 279-mm, XM390 DATE FIRED: 25 January 1960 ROUND NO.: 3

FILLER: Composition B

FRAGMENTS FROM WARHEAD

WEIGHT INTERVALS IN GRAIN		DISTRIBUTION OF FRAGMENTS BY NUMBER AND WEIGHTS										
		Zone 1	Zone 2	Zone 3	Zone 4	Zone 5	Zone 6	Zone 7	Zone 8	Zone 9	Zone 10	Zone 11
0 - 1	NO.	111	173	117	93	62	45	33	32	54	26	104
	WT.	29.50	53.25	32.29	31.40	22.48	16.75	12.50	7.22	16.90	7.44	25.86
1 - 2	NO.	20	22	25	23	8	5	5	7	14	8	19
	WT.	28.15	31.85	35.47	31.28	11.48	6.39	6.90	9.80	20.30	12.09	19.10
2 - 5	NO.	25	21	24	31	11	11	10	15	12	11	17
	WT.	76.04	58.03	80.20	97.20	36.80	38.80	29.28	45.80	37.30	40.50	53.20
5 - 8	NO.	4	8	14	6	13	1	6	6	10	6	6
	WT.	27.39	52.36	93.44	42.80	83.60	5.80	39.00	42.60	64.80	35.46	43.08
8 - 10	NO.		2	5	2	1		7		6	3	5
	WT.		19.00	44.27	18.80	9.69		64.00		55.72	29.10	46.22
10 - 15	NO.	1	5	6	6	11	6	4	8	5	2	3
	WT.	14.94	58.67	71.42	71.80	138.54	69.80	49.20	99.44	62.06	29.15	36.80
15 - 20	NO.		3	6	2	6		3	2	5	5	4
	WT.		54.65	101.05	33.60	102.52		51.00	35.00	89.60	93.40	71.80
20 - 25	NO.	1		2	2	3	2	4	4	1	1	4
	WT.	23.57		42.40	42.60	64.60	45.60	92.62	87.48	23.00	22.85	91.82
25 - 35	NO.		1	2	1	3	1	6	1	1	3	4
	WT.		26.57	54.80	25.52	80.20	28.60	172.00	28.50	35.00	97.20	121.42
35 - 50	NO.		1	3		1	2			1	3	2
	WT.		40.00	120.00		40.00	84.86			45.60	127.40	81.60
50 - 60	NO.			2					2	1		1
	WT.			108.32					103.00	58.60		51.00
60 - 70	NO.		2							1	1	
	WT.		131.20							61.60	63.84	
70 - 80	NO.	1	1									
	WT.	73.90	72.60									
80 - 90	NO.											
	WT.											
90 - 100	NO.	1	1									1
	WT.	92.52	96.60									91.62

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FRAGMENT RECOVERY

TYPE: 279-mm, XM390 DATE FIRED: 25 January 1960 ROUND NO.: 3

FILLER: Composition B

FRAGMENTS FROM WARHEAD

WEIGHT INTERVALS IN GRAIN		DISTRIBUTION OF FRAGMENTS BY NUMBER AND WEIGHTS										
		Zone 1	Zone 2	Zone 3	Zone 4	Zone 5	Zone 6	Zone 7	Zone 8	Zone 9	Zone 10	Zone 11
100 - 125	NO.	1									1	
	WT.	111.00									116.60	
125 - 150	NO.	1		1								
	WT.	143.00		131.00								
150 - 200	NO.	1	1	1							1	
	WT.	150.00	152.00	174.00							174.00	
200 - 250	NO.											
	WT.											
250 - 300	NO.	1										
	WT.	255.00										
300 - 400	NO.											
	WT.											
400 - 500	NO.		1									
	WT.		413.00									
500 - 750	NO.											
	WT.											
750 - 1000	NO.											
	WT.											
1000 and Over	NO.	1										
	WT.	3759.00										
	NO.											
	WT.											
	NO.											
	WT.											
	NO.											
	WT.											
	NO.											
	WT.											
Total	NO.	169	242	208	166	119	73	78	77	111	71	170
	WT.	4784.01	1259.78	1088.66	395.00	589.91	296.60	516.50	458.84	570.48	849.03	733.52

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FRAGMENT RECOVERY

TYPE: 279-mm, XM390 DATE FIRED: 25 January 1960 ROUND NO.: 3

FILLER: Composition B

FRAGMENTS FROM WARHEAD

WEIGHT INTERVALS IN GRAIN		DISTRIBUTION OF FRAGMENTS BY NUMBER AND WEIGHTS									Total No.	Total Weight
		Zone 12	Zone 13	Zone 14	Zone 15	Zone 16	Zone 17	Zone 18	Zone 19			
0 - 1	NO.	53	103	328	326	369	987	511	67		3594	
	WT.	13.50	27.08	99.84	100.16	84.38	185.46	68.60	12.36			846.97
1 - 2	NO.	13	23	44	58	37	59	20	4		414	
	WT.	17.30	34.20	63.12	83.02	53.28	85.60	27.21	4.11			580.65
2 - 5	NO.	13	21	32	39	35	64	11			403	
	WT.	46.40	62.80	98.94	117.52	103.80	195.80	31.65				1250.06
5 - 8	NO.	9	6	15	9	5	13	2			139	
	WT.	63.22	39.00	94.92	55.74	32.78	82.86	11.69				910.54
8 - 10	NO.	2	1	4	7		4	1			50	
	WT.	17.80	9.37	36.76	59.78		37.18	9.58				457.27
10 - 15	NO.	4	5	10	2	3	4				85	
	WT.	56.72	63.20	118.31	24.06	38.82	47.14					1050.07
15 - 20	NO.	4		1	1		3				45	
	WT.	70.60		19.74	16.46		52.20					791.62
20 - 25	NO.	1	1	1			1				28	
	WT.	21.26	23.26	20.16			24.80					626.02
25 - 35	NO.	3	3				2				31	
	WT.	80.34	102.00				57.96					910.11
35 - 50	NO.		1								14	
	WT.		36.26									575.72
50 - 60	NO.		1								7	
	WT.		56.00									376.92
60 - 70	NO.		1								5	
	WT.		68.84									325.48
70 - 80	NO.										2	
	WT.											146.50
80 - 90	NO.											
	WT.											
90 - 100	NO.										3	
	WT.											280.74

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FRAGMENT RECOVERY

TYPE: 279-mm, XM390 DATE FIRED: 25 January 1960 ROUND NO.: 3

FILLER: Composition B

FRAGMENTS FROM WARHEAD

WEIGHT INTERVALS IN GRAIN		DISTRIBUTION OF FRAGMENTS BY NUMBER AND WEIGHTS										
		Zone 12	Zone 13	Zone 14	Zone 15	Zone 16	Zone 17	Zone 18	Zone 19		Total No.	Total Weight
100 - 125	NO.										2	
	WT.											227.60
125 - 150	NO.										2	
	WT.											274.00
150 - 200	NO.										4	
	WT.											650.00
200 - 250	NO.											
	WT.											
250 - 300	NO.										1	
	WT.											255.00
300 - 400	NO.											
	WT.											
400 - 500	NO.										1	
	WT.											413.00
500 - 750	NO.											
	WT.											
750 - 1000	NO.											
	WT.											
1000 and Over	NO.								2		3	
	WT.								40515.00			4274.00
	NO.											
	WT.											
	NO.											
	WT.											
	NO.											
	WT.											
	NO.											
	WT.											
Total	NO.	102	166	435	442	449	1137	545	73		4833	
	WT.	387.14	522.01	551.79	456.74	313.06	769.00	148.73	40531.47			55222.21

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FRAGMENT RECOVERY

TYPE: 279-mm, XM390 **DATE FIRED:** 25 January 1960 **ROUND NO.:** 3

FILLER: Composition B

FRAGMENTS FROM OUTER CASE (ALUMINUM)

WEIGHT INTERVALS IN GRAIN		DISTRIBUTION OF FRAGMENTS BY NUMBER AND WEIGHTS										
		Zone 1	Zone 2	Zone 3	Zone 4	Zone 5	Zone 6	Zone 7	Zone 8	Zone 9	Zone 10	Zone 11
0 - 1	NO.	No	No	No	No	No	No	No	No		8	45
	WT.										3.47	14.35
1 - 2	NO.	R	R	R	R	R	R	R	R	1	4	3
	WT.	e	e	e	e	e	e	e	e	1.89	6.80	4.37
2 - 5	NO.	c	c	c	c	c	c	c	c	1	2	6
	WT.	o	o	o	o	o	o	o	o	3.55	7.32	18.53
5 - 8	NO.	v	v	v	v	v	v	v	v			6
	WT.	e	e	e	e	e	e	e	e			38.46
8 - 10	NO.	r	r	r	r	r	r	r	r			1
	WT.	y	y	y	y	y	y	y	y			9.60
10 - 15	NO.										2	2
	WT.										22.85	24.70
15 - 20	NO.									1	2	1
	WT.									18.74	32.84	16.00
20 - 25	NO.											1
	WT.											21.06
25 - 35	NO.											2
	WT.											52.04
35 - 50	NO.											2
	WT.											84.62
50 - 60	NO.											1
	WT.											51.06
60 - 70	NO.											
	WT.											
70 - 80	NO.											
	WT.											
80 - 90	NO.											
	WT.											
90 - 100	NO.	-	-	-	-	-	-	-	-			
	WT.	-	-	-	-	-	-	-	-			

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FRAGMENT RECOVERY

TYPE: 279-mm, XM390 **DATE FIRED:** 25 January 1960 **ROUND NO.:** 3

FILLER: Composition B

FRAGMENTS FROM OUTER CASE (ALUMINUM)

WEIGHT INTERVALS IN GRAIN		DISTRIBUTION OF FRAGMENTS BY NUMBER AND WEIGHTS										
		Zone 1	Zone 2	Zone 3	Zone 4	Zone 5	Zone 6	Zone 7	Zone 8	Zone 9	Zone 10	Zone 11
100 - 125	NO.											
	WT.											
125 - 150	NO.											
	WT.											
150 - 200	NO.											
	WT.											
200 - 250	NO.											
	WT.											
250 - 300	NO.											
	WT.											
300 - 400	NO.											
	WT.											
400 - 500	NO.											
	WT.											
500 - 750	NO.											
	WT.											
750 - 1000	NO.											
	WT.											
1000 and Over	NO.											
	WT.											
	NO.											
	WT.											
	NO.											
	WT.											
	NO.											
	WT.											
	NO.											
	WT.											
Total	NO.	-	-	-	-	-	-	-	-	3	18	70
	WT.	-	-	-	-	-	-	-	-	24.18	73.28	334.79

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FRAGMENT RECOVERY

TYPE: 279-mm, XM390 DATE FIRED: 25 January 1960 ROUND NO.: 3

FILLER: Composition B

FRAGMENTS FROM OUTER CASE (ALUMINUM)

WEIGHT INTERVALS IN GRAIN		DISTRIBUTION OF FRAGMENTS BY NUMBER AND WEIGHTS										
		Zone 12	Zone 13	Zone 14	Zone 15	Zone 16	Zone 17	Zone 18	Zone 19		Total No.	Total Weight
0 - 1	NO.	50	24	27	81	119	193	115	3		665	
	WT.	19.09	8.75	7.06	25.56	36.36	48.65	16.17	0.37			179.83
1 - 2	NO.	6	13	14	9	12	8	3			73	
	WT.	8.14	19.34	19.92	11.90	16.46	11.96	4.38				105.16
2 - 5	NO.	10	11	13	13	8	5	2			71	
	WT.	32.40	35.82	42.76	42.64	20.50	15.95	4.50				223.97
5 - 8	NO.	2	1	2		4	3				18	
	WT.	12.02	5.79	12.24		24.88	20.95					114.34
8 - 10	NO.	3	2		2		2				10	
	WT.	27.20	18.80		18.64		17.66					91.90
10 - 15	NO.	2		1	3	1					11	
	WT.	27.57		12.01	32.10	11.01						130.24
15 - 20	NO.	1				1					6	
	WT.	17.40				19.59						104.57
20 - 25	NO.	1				2					4	
	WT.	23.98				44.40						89.44
25 - 35	NO.	5									7	
	WT.	152.00										204.04
35 - 50	NO.	3				2					7	
	WT.	135.20				92.68						312.50
50 - 60	NO.					1					2	
	WT.					57.74						108.80
60 - 70	NO.	1									1	
	WT.	61.60										61.60
70 - 80	NO.					1					1	
	WT.					77.52						77.52
80 - 90	NO.											
	WT.											
90 - 100	NO.											
	WT.											

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FRAGMENT RECOVERY

TYPE: 279-mm, XM390 DATE FIRED: 25 January 1960 ROUND NO.: 3

FILLER: Composition B

FRAGMENTS FROM OUTER CASE (ALUMINUM)

WEIGHT INTERVALS IN GRAIN		DISTRIBUTION OF FRAGMENTS BY NUMBER AND WEIGHTS										
		Zone 12	Zone 13	Zone 14	Zone 15	Zone 16	Zone 17	Zone 18	Zone 19		Total No.	Total Weight
100 - 125	NO.											
	WT.											
125 - 150	NO.											
	WT.											
150 - 200	NO.											
	WT.											
200 - 250	NO.											
	WT.											
250 - 300	NO.											
	WT.											
300 - 400	NO.											
	WT.											
400 - 500	NO.											
	WT.											
500 - 750	NO.											
	WT.											
750 - 1000	NO.											
	WT.											
1000 and Over	NO.								1		1	
	WT.								18620.00			18620.00
	NO.											
	WT.											
	NO.											
	WT.											
	NO.											
	WT.											
	NO.											
	WT.											
Total	NO.	84	51	57	108	151	211	120	4		877	
	WT.	516.60	88.50	93.99	130.84	401.14	115.17	25.05	18620.37			20423.91

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FRAGMENT RECOVERY

TYPE: 279-mm, XM390 **DATE FIRED:** 25 January 1960 **ROUND NO.:** 3

FILLER: Composition B

FRAGMENTS RECOVERED FROM NOSE AND BASE

WEIGHT INTERVALS IN GRAIN		DISTRIBUTION OF FRAGMENTS BY NUMBER AND WEIGHTS										
		Zone 1N	Zone 2N	Total	Zone 18B	Zone 19B	Total		Total Aluminum Frags	Total Warhead Frags		Grand Total All Frags
0 - 1	NO.	32	30	62	8	12	20		665	3594		4341
	WT.	11.86	10.75	22.61	2.88	5.36	8.24		179.83	846.97		1057.65
1 - 2	NO.	10	7	17	3	1	4		73	414		508
	WT.	13.51	10.33	23.84	4.42	1.35	5.77		105.16	580.65		715.42
2 - 5	NO.	10	8	18	3		3		71	403		495
	WT.	33.66	24.67	58.33	10.65		10.65		223.97	1250.06		1543.01
5 - 8	NO.	6	2	8					18	139		165
	WT.	38.62	12.15	50.77					114.34	910.54		1075.65
8 - 10	NO.	2	2	4	1		1		10	50		65
	WT.	16.58	18.96	35.54	8.45		8.45		91.90	457.27		593.16
10 - 15	NO.	5		5					11	85		101
	WT.	65.60		65.60					130.24	1050.07		1245.91
15 - 20	NO.	1	1	2					6	45		53
	WT.	18.84	18.64	37.48					104.57	791.62		933.67
20 - 25	NO.	1	2	3					4	28		35
	WT.	20.16	45.00	65.16					89.44	626.02		780.62
25 - 35	NO.								7	31		38
	WT.								204.04	910.11		1114.15
35 - 50	NO.	2		2					7	14		23
	WT.	98.00		98.00					312.50	575.72		986.22
50 - 60	NO.	1	1	2					2	7		11
	WT.	56.60	54.48	112.08					108.80	376.92		597.80
60 - 70	NO.								1	5		6
	WT.								61.60	325.48		387.08
70 - 80	NO.								1	2		3
	WT.								77.52	146.50		224.02
80 - 90	NO.											
	WT.											
90 - 100	NO.									3		3
	WT.									280.74		280.74

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FRAGMENT RECOVERY

TYPE: 279-mm, XM390 **DATE FIRED:** 25 January 1960 **ROUND NO.:** 3

FILLER: Composition B

FRAGMENTS RECOVERED FROM NOSE AND BASE

WEIGHT INTERVALS IN GRAIN	DISTRIBUTION OF FRAGMENTS BY NUMBER AND WEIGHTS											
		Zone 1N	Zone 2N	Total	Zone 18B	Zone 19B	Total		Total Aluminum Frags	Total Warhead Frags		Grand Total All Frags
100 - 125	NO.									2		2
	WT.									227.60		227.60
125 - 150	NO.									2		2
	WT.									274.00		274.00
150 - 200	NO.									4		4
	WT.									650.00		650.00
200 - 250	NO.											
	WT.											
250 - 300	NO.									1		1
	WT.									255.00		255.00
300 - 400	NO.											
	WT.											
400 - 500	NO.									1		1
	WT.									413.00		413.00
500 - 750	NO.											
	WT.											
750 - 1000	NO.											
	WT.											
1000 and Over	NO.								1	3		4
	WT.								18620.00	44274.00		62894.00
	NO.											
	WT.											
	NO.											
	WT.											
	NO.											
	WT.											
	NO.											
	WT.											
Total	NO.	70	53	123	15	13	28		877	4833		5861
	WT.	373.43	195.98	569.41	26.40	6.71	33.11		20423.91	55222.27		76248.70

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3.3 Analysis of Data

(U) The initial velocity (V_o) of the fragments was obtained by using the following equation:

$$V_o = V_p \, e^{\frac{ar}{m_r^{1/3}}} - 1 \Big/ \frac{ar}{m_r^{1/3}} \quad \text{where}$$

V_p = photographic velocity, fps.
r = distance from projectile to target, feet.
m_r = the representative fragment weight, grains.
a = $12 K_{dp} K^{-2/3}$; where K is the fragment shape factor, p is the air density in grains/inch^3, and K_d is the representative fragment drag coefficient.

(U) For a more complete and detailed definition see Appendix B.

(U) Since no separation of the photographic velocities was possible for the two types of metal, the initial velocities were computed using the drag characteristics for steel fragments. These initial velocities were then considered applicable to both the steel and aluminum fragments.

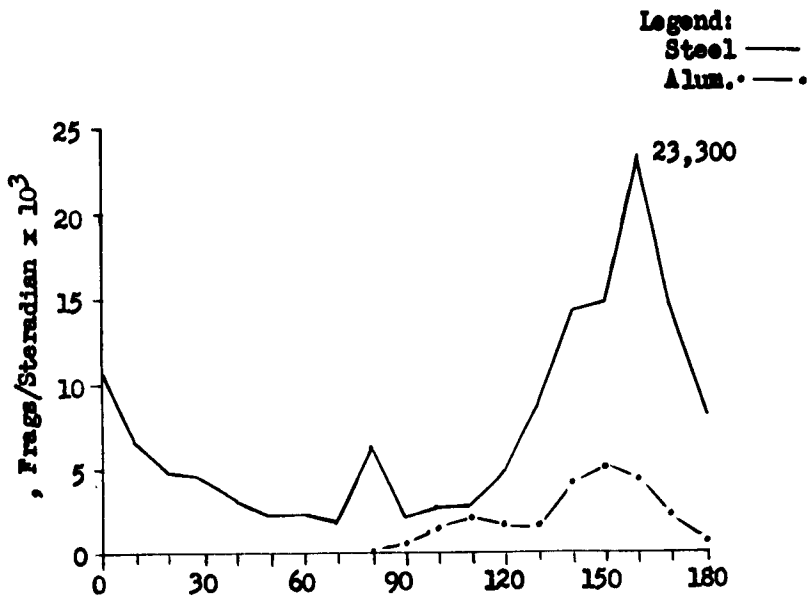
(U) The initial fragment velocities, and the density of fragments per steradian for each 10-degree increment, are shown in Table V. See Figure 8 for a graph of density and initial velocity.

Table V (S). Average Fragment Velocity and Density, Rounds 1, 2, and 3

Zone	Degree	Initial Velocity, fps	Density, Fragments per Steradian	
			Steel	Aluminum
1	0	3300	10287	a
2	10	3700	6324	a
3	20	4550	4525	a
4	30	4900	4414	a
5	40	5050	3032	a
6	50	5050	2145	a
7	60	5300	2239	a
8	70	5450	1785	a
9	80	5350	6272	192
10	90	4900	2095	599
11	100	5000	2672	1479
12	110	4650	2735	2046
13	120	5150	4713	1648
14	130	6350	8963	1642
15	140	6200	14206	4102
16	150	5600	14638	5077
17	160	4700	23360	4414
18	170	3950	14363	2238
19	180	3500	8491	698

[a]No aluminum fragments recovered in Zones 1 to 9.

AVERAGE FRAGMENT DENSITY, , vs ANGLE θ



AVERAGE INITIAL VELOCITY, V_o, vs ANGLE θ

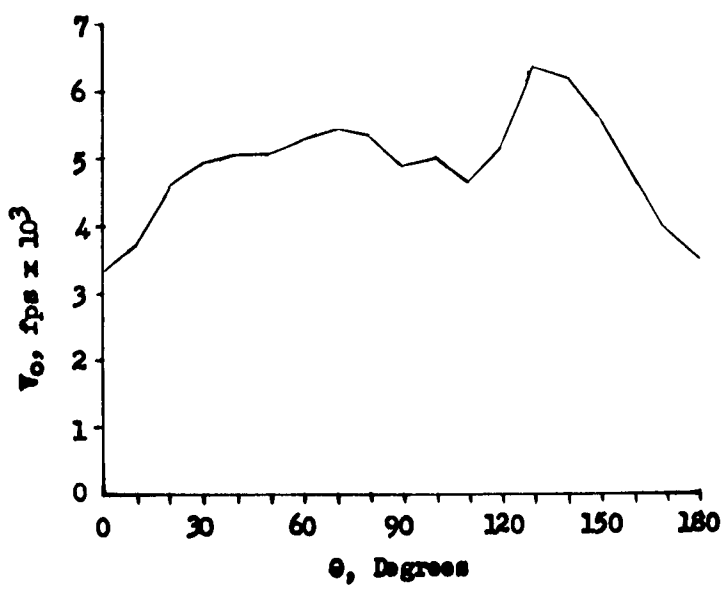


Figure 8

(U) Table VI presents the number and weight of fragments recovered.

Table VI (S). Actual Fragment Recovery

Round No.	Steel Fragments: Total[a] Weight, gr	Steel Fragments: Total[a] No.	Steel Fragments: Average[b] Weight, gr	Aluminum Fragments: Total[a] Weight, gr	Aluminum Fragments: Total[a] No.	Aluminum Fragments: Average[c] Weight, gr
1	54,623.25	5366	2.07	21,224.33	810	2.87
2	54,876.13	4047	2.83	20,638.44	709	2.65
3	55,824.79	4984	2.32	20,423.91	877	2.06

[a]Including fragment recovery from the extra nose and base boxes placed at 35 feet.

[b]The average steel fragment weights were determined by excluding large fuze and antenna pieces which did not break up. From all three rounds one large fuze fragment weighing approximately 4500 grains was recovered. From rounds 1 and 2, one large piece of the antenna weighing 38,500 grains was recovered, and from round 3 two large pieces with a combined weight of 40,515 grains were recovered.

[c]The average aluminum fragment weights were determined by excluding one large fragment, weighing approximately 18,750 grains, from all rounds. This fragment was from the rear part of the projectile body.

(U) Table VII presents the integrated fragment data.

Table VII (S). Integrated Recovery Data

Rd No.	All Fragments: As Fired Wt, lb	All Fragments: Integrated Wt, lb	All Fragments: No. of Frags	All Fragments: Per Cent Recovery	Excluding Large Fragments: Integrated Wt, lb	Excluding Large Fragments: No. of Frags	Excluding Large Fragments: Avg Frag Wt, gr
			Steel Fragments				
1	34.95	28.28	59,860	80.9	22.05	59,858	2.58
2	34.90	27.16	47,937	77.8	20.95	47,935	3.06
3	34.68	28.68	59,410	82.7	22.36	59,407	2.63
			Aluminum Fragments				
1	10.73	8.93	11,164	83.2	6.23	11,163	3.90
2	10.73	7.64	10,476	71.2	4.96	10,475	3.32
3	10.73	7.44	12,099	69.4	4.78	12,098	2.77

(U) Table VIII presents the integrated data scaled to 100 per cent recovery.

Table VIII (S). Integrated Data Scaled to 100 Per Cent Recovery

Round No.	Scaled No. of Fragments	Weight Scaled Excluding Large Fragments, lb	Average Fragment Weight Excluding Large Fragments, gr
		Steel Fragments	
1	73,986	27.25	2.58
2	61,598	26.92	3.06
3	71,826	27.04	2.63
Average	69,137	27.07	2.74
		Aluminum Fragments	
1	13,419	7.48	3.90
2	14,708	6.97	3.32
3	17,447	6.90	2.77
Average	15,191	7.12	3.28

(U) The total number of fragments produced was determined by the following equation:

$$N = 2\pi \int_0^{\pi} \sigma(\theta) \sin\theta \, d\theta$$

where $\sigma(\theta)$ = Scaled number of fragments per unit solid angle (Steradian).
θ = Angle from axis of shell as measured from the nose. See Table V for fragment density per steradian.

(U) Table IX presents the per cent of weight and number of the scaled fragments (100 per cent) for each weight interval based on the averages of all three rounds.

Table IX (S). Per Cent of Weight and Number of the Scaled Fragments for Each Weight Interval

Weight Interval, gr	Steel Fragments: Per Cent of Weight	Steel Fragments: Per Cent of Number	Steel Fragments: Average Weight, gr	Aluminum Fragments: Per Cent of Weight	Aluminum Fragments: Per Cent of Number	Aluminum Fragments: Average Weight, gr
0 - 1	4.84	69.56	0.25	4.13	66.10	0.31
1 - 2	3.85	9.48	1.43	2.85	9.98	1.42
2 - 5	8.51	9.42	3.18	6.89	10.31	3.30

Weight Interval, gr	Steel Fragments: Per Cent of Weight	Steel Fragments: Per Cent of Number	Steel Fragments: Average Weight, gr	Aluminum Fragments: Per Cent of Weight	Aluminum Fragments: Per Cent of Number	Aluminum Fragments: Average Weight, gr
5 - 8	6.79	3.75	6.38	4.67	3.66	6.31
8 - 10	3.74	1.48	8.94	3.57	1.95	9.02
10 - 15	7.50	2.18	12.12	5.02	2.06	12.06
15 - 20	5.88	1.21	17.22	4.08	1.19	16.93
20 - 25	4.97	0.78	22.36	5.14	1.12	22.68
25 - 35	7.19	0.87	29.29	10.00	1.71	28.88
35 - 50	5.75	0.49	41.10	10.14	1.19	42.00
50 - 60	3.43	0.23	53.55	2.50	0.24	52.58
60 - 70	3.53	0.19	64.55	2.62	0.20	65.75
70 - 80	2.22	0.11	73.92	2.55	0.17	75.69
80 - 90	1.00	0.04	84.41			
90 - 100	1.83	0.07	92.36	2.15	0.12	90.74
100 - 125	1.37	0.04	110.84			
125 - 150	0.95	0.02	136.35			
150 - 200	2.18	0.05	167.22			
200 - 250	0.91	0.02	208.25			
250 - 300	0.04	a	255.00			
300 - 400	0.07		384.00			
400 - 500	0.39		429.95			
500 - 750	0.42		650.06			
750 - 1000	0.35		789.86			
Over 1000	22.30		18,822.02	33.69	0.01	18,751.70

[a]Combining the weight intervals of 250 grains and above, the total number of steel fragments is 0.012 per cent.

(S) The tabulation of Tables VIII and IX shows that an extremely large number of fragments results from this projectile. From an average of three rounds, 70 per cent and 66 per cent of the steel and aluminum fragments, respectively, are in the smallest weight interval, 0 to 1 grain. This high percentage of fragments accounts for only 4 to 5 per cent of the total weight of both steel and aluminum. It is also in this weight interval that the difference of approximately 11,000 fragments occurs between the number of steel fragments for Round 2 and that of the other two rounds. The number of fragments excluding fragments in the 0 to 1 grain weight interval is given in Table X.

Table X (S). Scaled Number of Fragments, Excluding Fragments in 0 to 1 Grain Weight Interval

Round Number	Steel Fragments: Number	Steel Fragments: Per Cent	Aluminum Fragments: Number	Aluminum Fragments: Per Cent
1	19,516	26.4	4327	32.2
2	21,144	34.3	5488	37.3
3	22,480	31.3	5635	32.3
Average	21,048	30.4	5150	33.9

4. (S) CONCLUSIONS

It is concluded that:

a. Projectile, 279-mm, XM390, Composition B loaded, will produce an average of 69,137 steel fragments with average weight of 2.74 grains, and an average of 15,191 aluminum fragments with an average weight of 3.28 grains, with a mean initial velocity of 4876 feet per second.

b. Seventy per cent of the total number of scaled steel fragments were in the weight interval of 0 to 1 grain.

c. Sixty-six per cent of the total number of scaled aluminum fragments were in the weight interval of 0 to 1 grain.

d. A lethality study is being conducted by Weapons Systems Laboratory, BRL and the results will be included in their report.

5. (S) RECOMMENDATIONS

In view of the high number of small fragments (0 to 1 grain) produced by the pearlitic malleable iron warhead, further study should be conducted using another explosive filler. Since the brisance of TNT is less than that of Composition B, it is recommended that the warhead be tested using TNT as an explosive filler.

SUBMITTED:

J. T. Dempsey

J. T. DEMPSEY
Ordnance Technician

REVIEWED:

V. L. Grafton

V. L. GRAFTON
Chief, Terminal Effects
and Special Projects Branch

Claude E Brown

C. E. BROWN
Chief, Infantry and
Aircraft Weapons Division

APPROVED:

H. A. Noble

H. A. NOBLE
Assistant Deputy Director
for Engineering Testing
Development and Proof Services

REFERENCES (U)

1. Technical Memorandum Report ORDBB-TE5-12. Feltman Research and Engineering Laboratories, Picatinny Arsenal, Dover, N. J.

2. Technical Memorandum Report ORDBB-TK-391. Feltman Research and Engineering Laboratories, Picatinny Arsenal, Dover, N. J.

APPENDICES (U)

APPENDIX A
Correspondence 6

ORDNANCE CORPS
PICATINNY ARSENAL
DOVER, NEW JERSEY Mr. E. Barrieres/ss/2277

IN REPLY
REFER TO:
FELTMAN RESEARCH AND ENGINEERING LABORATORIES
ORDBB-TE5

OCT 8 '59 12 PM

SUBJECT: Projectile, Atomic, 279MM, Practice, Spotting, XM390, (Project TN2-8051) (C)

TO: Commanding General
Aberdeen Proving Ground
Aberdeen, Maryland
ATTENTION: ORDBG-DP-TI, Mr. M. Raabe

(C) 1. It is requested that complete fragmentation data be obtained for the XM390 Projectile at various heat treat conditions on the malleable iron warhead. Three projectiles are furnished incorporating warheads of 70,000 psi minimum yield, three of 50,000 psi minimum yield and two each of 32,500 psi minimum yield. The desired data should include fragment velocity, fragment mass and spatial distribution. This data should be segregated by heat treatment in order to evaluate the effect of heat treat on lethality. Fragment velocity is expected to be in the order of 6,000 ft./sec.

(U) 2. It is desired that the Analytical Laboratory oversee the test procedure and set-up. Further, it is desired that the Analytical Laboratory reduce the data obtained and put the information in a form acceptable to the Weapons Systems Laboratory of the Ballistic Research Laboratories.

(U) 3. The Weapons Systems Laboratory of BRL is requested to calculate the lethality of each of the three heat treat conditions based on the fragmentation data furnished.

(U) 4. The average metal parts weight of the warhead alone is approximately 27 pounds; the charge is 16.33 pounds of Composition B. The actual measured metal parts weight and charge weight will be included on data cards which will accompany the shipment.

(C) 5. Drawing No. AA-44-929, inclosed, shows the complete projectile assembly. Only the outer envelope of the projectile will be used; i.e., only those components affecting fragment velocity or distribution. Also inclosed is Drawing AA-44-921: the warhead loading assembly.

ORDBB-TE5
SUBJECT: Projectile, Atomic, 279MM, Practice, Spotting, XM390 (Project TN2-8051)(C)

(U) 6. Funds for this work are available at your Proving Ground on Project TN2-8051, OMS Code #5530.12.533AD.12.

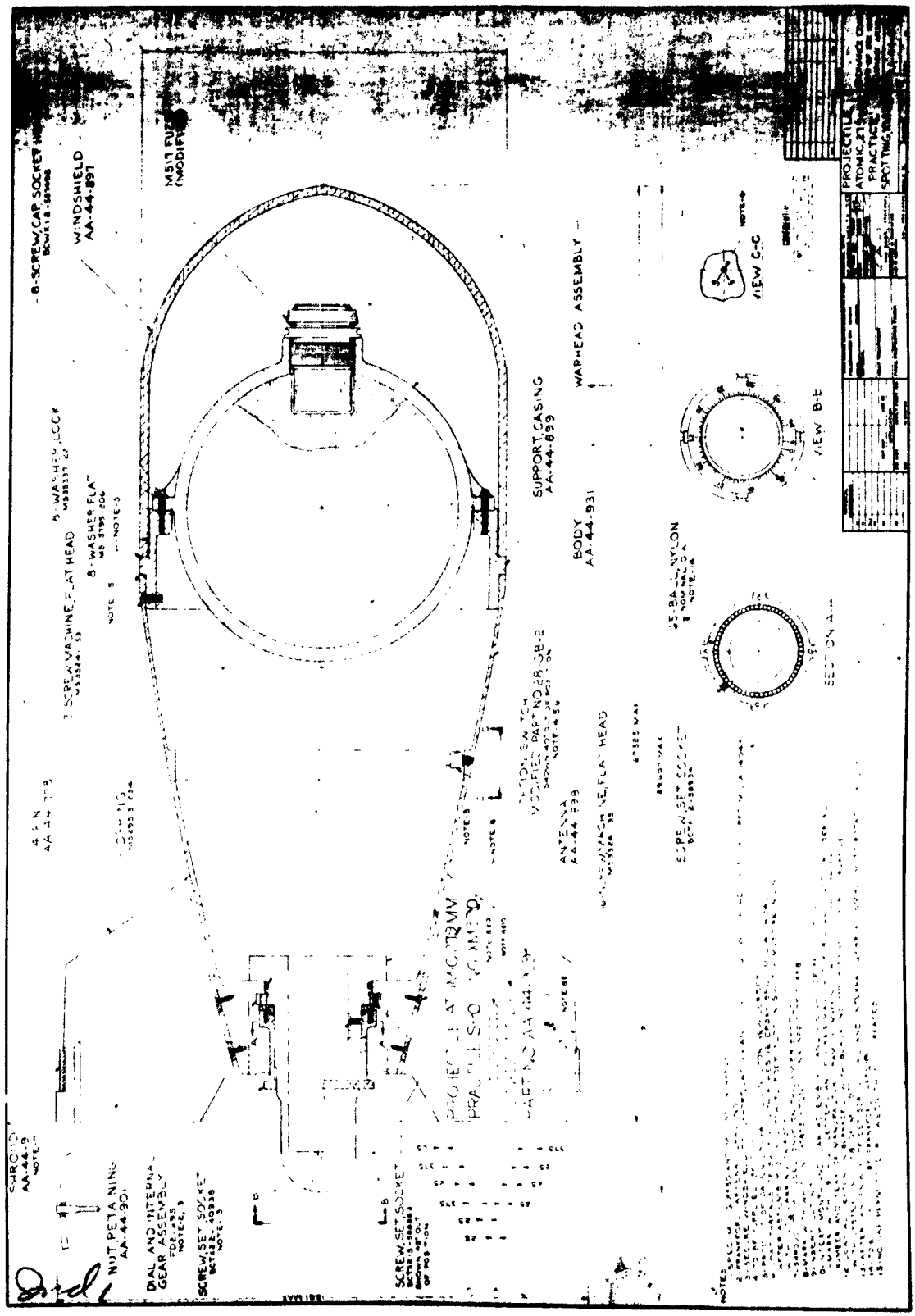
(S) 7. Since this item is part of the Davy Crockett program, test scheduling and data reduction should be conducted as soon as possible in accordance with the high priority assigned to this program. It is desired that notification of the test date be furnished at least three days in advance of the test to permit attendance by interested Arsenal personnel.

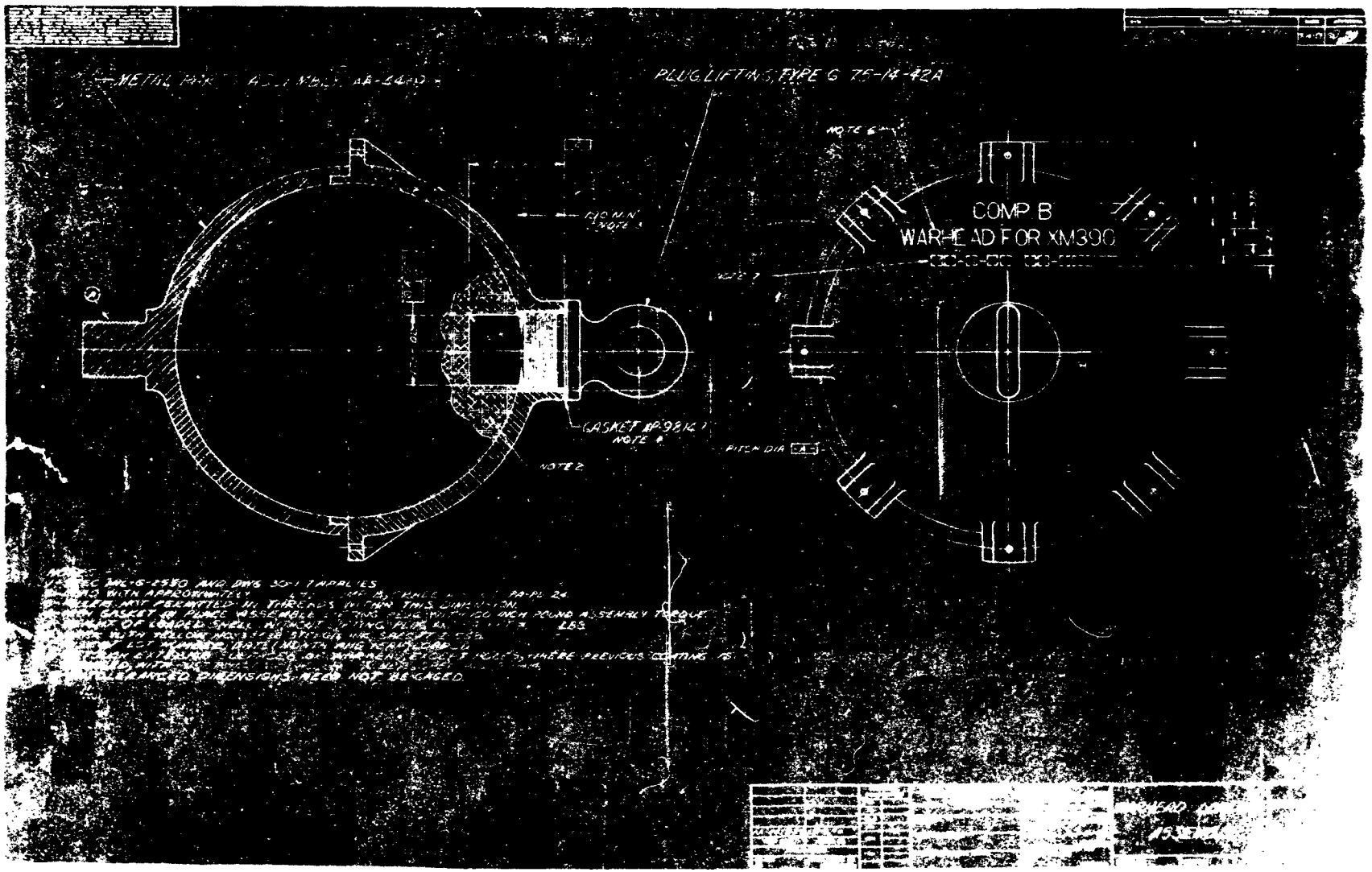
FOR THE COMMANDER:

J. A. DUBIN
Assistant

2 Incls
1. Dwg. No. AA-44-929 (C)
2. Dwg. No. AA-44-921 (U)

CC:
APG, ORDBG-D&PS w/o Incls
Analytical Lab
APG, ORDBG-BRL w/o Incls
Weapons Systems Lab.
OSWAC w/o Incls


WINDSHIELD
AA-44-897
SUPPORT, CASING
AA-44-899
WARHEAD ASSEMBLY
BODY
AA-44-931
ANTENNA
AA-44-939
DIAL AND INTERNAL GEAR ASSEMBLY
NUT, PETAINING
AA-44-901
SCREW, SET, SOCKET
VIEW C-C
VIEW B-B
PROJECTILE, ATOMIC, 37MM
PRACTICE
SPOTTING


PLUG LIFTING TYPE G 75-14-42A
COMP B
WARHEAD FOR XM390
GASKET AP 9814
NOTE 2
PITCH DIA

ORDNANCE CORPS
PICATINNY ARSENAL
DOVER, NEW JERSEY Mr. EBarrieres/ss/6208

IN REPLY
REFER TO:
FELTMAN RESEARCH AND ENGINEERING LABORATORIES
ORDBB-TE5

JAN 14 '59 -3 PM

SUBJECT: Weights of Components of XM390 Fragmentation Projectiles

TO: Commanding General
Aberdeen Proving Ground
Aberdeen, Maryland
ATTENTION: ORDBG-DP-TI, Mr. H. Raabe

1. In accordance to your request, forwarded are the component weights of the XM390 fragmentation test projectiles, lot number PA-E-30478. Actual measured weights were not recorded for the shell components so that the weights supplied are nominal weights for each component. Individual serialized weights are supplied for the warheads metal parts assembly, loaded warhead, and assembled projectile.

2. It will be noted that weights are supplied for those components of the incomplete projectile as supplied for testing. Not included were the Fin, Shroud, Setting Dial, Option Switch, and Tactical Fuze.

Shell Component Weights:

Windshield, AA-44-897	5.92#
Antenna, AA-44-898 including Retaining Nut, AA-44-901	5.85#
Casing Support, AA-44-899	3.35#
Body, AA-44-931	7.38#

Serialized Warhead Weights:

Warhead s/n PA-64-59.	
Metal Parts (unloaded)	27.6#
Loaded Warhead	44.23#
Comp. B charge (by difference)	16.63#
Total Projectile Weight*	66.5#
Warhead s/n PA-65-59	
Metal Parts	27.53#
Loaded Warhead	44.00#
Comp. B charge	16.47#
Total Projectile Weight*	66.80#

*Projectile Weight measured with lifting plug installed in warhead.

CRDBB-TE5
SUBJECT: Weights of Components of XM390 Fragmentation Projectiles

Warhead s/n PA-66-59	
Metal Parts	27.33#
Loaded Warhead	44.00#
Comp. B charge	16.67#
Total Projectile Weight*	65.90#

FOR THE COMMANDER:

E H Buchanan

E. H. BUCHANAN
Assistant

APPENDIX B

Analytical Laboratory Report 60-AL-34
14 March 1960

Title: Results of Fragmentation Test of 279mm Projectile, XM390

Project No.: TN2-8051/100

Prepared for: Bomb & Fragmentation Branch, Inf & Acft Wpns Div

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(U) INTRODUCTION

A static fragmentation test was conducted to obtain velocity, mass and spatial distribution of fragments for the 279mm, XM390 Projectile. Three rounds were tested for this purpose. These rounds were Comp B loaded and had warheads of pearlitic malleable iron with a yield strength of 50,000 psi. Also, the rounds were tested without the fin assembly. This report discusses the procedure used to obtain the data and presents the data in the form required by EDVAC for lethality studies.

(U) DESCRIPTION OF TEST ARENA

A square fragmentation arena was used for this test. In this arrangement, the recovery area consists of 4 ft by 8 ft sheets of cellotex stacked to a suitable depth and placed in a rectangular pattern from 0° to 180° as measured from the nose to the base of the shell. The other side of the arena, also rectangular, was used for velocity measurement. The velocity panels consist of 4 ft by 8 ft sheets of 0.020 inch dural with photoflash bulbs mounted behind them for backlighting, and aluminum foil to serve as a reflection surface.

Since the shell is symmetrical about its axis, the fragmentation characteristics are assumed to be symmetric, i.e., the fragment velocity, density, and spatial distribution obtained from one region are assumed to be equivalent to those of the symmetrically located region. Because of the possibility of irregular shell break-up in the nose and base areas, recovery boxes were placed outside the velocity targets at the nose and base ends.

The recovery area was divided into angular intervals or zones, numbered 1 through 19, from the nose to the base of the shell. Zones 1 and 19 covered the angular interval 0° to 5° and 175° to 180°, respectively, as measured from the axis of the projectile. Zones 2 through 18 covered the angle from 5° to 175° for each interval of 10°. The extra recovery boxes were placed at the nose, to recover fragments in areas symmetric to Zones 1 and 2, and at the base to recover fragments in areas symmetric to Zones 18 and 19. The rounds for this test were located with the base (antenna) directed toward 180°.

The velocity panels were also divided into zones corresponding to those of the recovery area. To aid in locating hits on the film for velocity measurements, horizontal lines 2 feet apart, were painted on the panels.

A sketch of the test arena is shown in Figure 1, Inclosure 1.

(U) PROCEDURE FOR COLLECTING DATA

Weight of Fragments

After each round was detonated, the fragments were recovered from the cellotex, located with regard to zone, separated according to type of metal (steel or aluminum), and weighed to an accuracy of 1% or a minimum of 0.01 grains.

Velocity of Fragments

High speed cameras (approximately 10,000 frames per second) were positioned so as to view the dural targets. The flashes of the fragment impacts on the dural were then recorded on the film record along with a millisecond time base. The flashbulb backlighting provided an additional source of light and made possible the recording of impacts that were produced by fragments with velocities too low (less than approximately 1700 fps) to produce a flash. The backlighting also provided more even illumination of each perforation then that normally obtained from impact alone. The photographic velocities, V_p, were determined from the time of flight for each fragment and the known travel distance. These distances from surface of shell to the target were calculated in such a manner that the error in the travel distance was less than 1%. The velocities were then grouped into the same angular intervals as the fragment weight data.

A detailed description of the methods used in collecting and reducing fragmentation data is contained in Report No. D&PS/Misc/306 dated September 1959.

(U) REDUCTION OF DATA

Initial Velocity of Fragments

The initial velocities, V_o, of the fragments for each angular interval were obtained from the equation

$$V_o = V_p \frac{e^{\frac{ar}{m_r^{1/3}}} - 1}{\frac{ar}{m_r^{1/3}}}$$

where $a = 12 K_d \rho K^{-2/3}$; $K = \frac{m}{A^{3/2}}$

The parameters needed to evaluate V_o by this relation were obtained as follows:

V_p - Photographic velocity (fps) is the median of the velocities for each zone. These velocities were determined by the relation r/t where r was the travel distance and t was the time of flight.

K_d - The value of K_d (Drag coefficient) = .64 was obtained by determining an average value for K_d over the range of fragment velocities. K_d as a function of Mach number for a particular shaped fragment was obtained from BRL Report No. M-915.

ρ - For air density a standard value of .304332 grains/in.^{3} (standard at APG) was adjusted to conditions at the time of firing by using the relative air density obtained from the Meteorological Section, Development and Proof Services.

K - The fragment shape factor was determined from the relationship $M/A^{-3/2}$ where m is the fragment weight in grains and $\bar{A}$ is the average presented area of the fragment. A sample of steel and aluminum fragments was selected from the fragmented rounds and the presented areas were measured by means of the icosahedron gage at BRL. From a least square fit of M and $\bar{A}$, values of 719 and 296 were determined for K for steel and aluminum fragments, respectively.

m_r - The representative fragment weight was determined as the fragment weight corresponding to the median of the number of fragments recovered but excluding the heavy fragments and those in the 0-1 grain interval.

Number and Density of Fragments

The scaled total number of steel and aluminum fragments for each round was calculated from the scaled fragment densities obtained from the recovery data. The total number of fragments N was calculated by the equation

$$N = 2\pi \int_0^{\pi} \sigma(\theta) \sin\theta \, d\theta$$

where θ is the angle from the nose end of the shell axis and $\sigma(\theta)$ is the scaled number of fragments per unit solid angle for each 10° interval. The term "scaled" refers to an adjustment of data based on the percent of recovery.

(U) RESULTS

The calculated results are tabulated for each round and for the three-round average in Inclosure 2. The data are arranged in the form required by the KDVAC code for the computation of lethal areas. The fragment spray density, and the median initial velocity, V_o, are given for each 10° interval from 0° to 180°.

The mean, m, of the fragment weights, in each weight interval and the ratio, q, of the number of fragments in each weight interval to the total number of fragments in the angular interval are given for each weight and angular interval.

It should be pointed out that the values of velocity, density, etc. that are tabulated for each angular interval, were computed from data obtained for a given angular width. Therefore, these are considered to be average values applicable at the midpoint of each angular interval, i.e., values given for $\theta = 60^{o}$ were derived from data obtained from $\theta = 55^{o}$ to $\theta = 65^{o}$.

Graphs

Graphs of the pertinent data: distribution of fragment weight and number, density, and velocity are presented in Figures 2-10, Inclosure 1.

(S) DISCUSSION OF RESULTS

The following table shows the weight data supplied by Picatinny Arsenal for the three rounds.

Weight in Pounds

Rd No.	Warhead Metal Parts	Explosive Filler	Antenna Assembly[a]	Casing Support & Body[a]	Wind-shield[a]	Total	Fuze[b]
1	27.60	16.63	5.85	10.73	5.92	66.50	1.50
2	27.53	16.47	5.85	10.73	5.92	66.80	1.52
3	27.33	16.67	5.85	10.73	5.92	65.90	1.50

[a]Nominal weights
[b]Modified M51A5 fuze supplied by APG

Two types of metal, steel and aluminum, were primarily involved in the fragments of these rounds. For the weight of the steel in each round, the weights of the warhead metal parts, antenna assembly and fuze were combined. For the aluminum components, the casing support and body, the nominal weight shown above was used for all three rounds. The windshield was non-metallic and appeared to be a molded plastic with cord reinforcing. No reduction of data was performed involving the windshield.

The weight and number of fragments actually recovered are as follows:

Actual Recovery Data

Rd. No.	Steel Fragments Total Wt, gr	Steel Fragments Total No.	Steel Fragments Ave Wt,[a] gr	Aluminum Fragments Total Wt, gr	Aluminum Fragments Total No.	Aluminum Fragments Ave Wt,[b] gr
1	54623.25	5366	2.07	21224.33	810	2.87
2	54876.13	4047	2.83	20638.44	709	2.65
3	55824.79	4984	2.32	20423.91	877	2.06

[a]The average steel fragment weights were determined by excluding large fuze and antenna parts which did not break up. For all three rounds one large fuze fragment weighing approximately 4500 grains was recovered. For Rounds 1 and 2, one large piece of the antenna weighing approximately 38,500 grains was recovered and for Round 3 two pieces of antenna with a combined weight of 40,515 grains were recovered.

[b]The average aluminum fragment weights were determined by excluding one large fragment weighing approximately 18,750 grains for all rounds. This fragment was from the rear part of the body around the antenna.

Integration of the actual recovery data to account for complete fragmentation data (360° around the axis of the shell) resulted in the values given in the following table.

Integrated Recovery Data

Rd. No.	All Frags Total Wt, lb	All Frags No. of Frags	Excluding Large Frags[c] Total Wt, lb	Excluding Large Frags[c] No. of Frags	Excluding Large Frags[c] Ave Frag Wt, gr
			Steel Fragments		
1	28.28	59,860	22.05	59,858	2.58
2	27.16	47,937	20.95	47,935	3.06
3	28.68	59,410	22.36	59,407	2.63
			Aluminum Fragments		
1	8.93	11,164	6.23	11,163	3.90
2	7.64	10,476	4.96	10,475	3.32
3	7.44	12,099	4.78	12,098	2.77

[c]See notes a and b above.

Since similar large fragments were recovered for all rounds for both the aluminum and steel, the recovery percentages were computed using the above total integrated weights. All rounds were then "scaled" or adjusted to 100 percent recovery. The recovery percentages and scaled data are presented for each round and the average of the three rounds in the following table.

	Steel Fragments				Aluminum Fragments			
Rd No.	As-fired Wt, lb	Percent Recovery	Scaled No. of Frags	Ave Frag Wt, gr	As-Fired Wt, lb	Percent Recovery	Scaled No. of Frags	Ave Frag Wt, gr
1	34.95	80.9	73,986	2.58	10.73	83.2	13,419	3.90
2	34.90	77.8	61,598	3.06	10.73	71.2	14,708	3.32
3	34.68	82.7	71,826	2.63	10.73	69.4	17,447	2.77
Ave	34.84	80.5	69,137	2.74		74.9	15,191	3.28

The above tabulation shows that an extremely high number of fragments results from this projectile. However, from the plot of the percent of weight and number of fragments versus weight interval, Figures 4 and 5, Inclosure 1, it can be seen that for the average of the three rounds 70% and 66% of the steel and aluminum fragments, respectively, are in the smallest weight interval, 0-1 grain but that these high percentages of fragments account for only 4-5% of the total weight of both steel and aluminum. It is also in this weight interval that the difference of approximately 11,000 fragments occurs between the number of steel fragments for Round 2 and that for Rounds 1 and 3. A comparison of the number of fragments excluding fragments in the 0-1 grain weight interval is given below.

Scaled Number of Fragments
Excluding Fragments in 0-1 Grain Weight Interval

Rd	Steel Fragments		Aluminum Fragments	
No.	Number	Percent of Total	Number	Percent of Total
1	19,519	26.4	4327	32.2
2	21,144	34.3	5488	37.3
3	22,480	31.3	5635	32.3
Ave	21,048	30.4	5150	33.9

Reference to the plot of accumulated number of all fragments versus angle θ, Figure 8, Inclosure 1, shows further that the differences in steel fragments for Round 2 occurred in the rear part of the projectile for an angle θ from approximately 120° to 160°.

The differences in the number of aluminum fragments for each round could not be resolved by eliminating the 0-1 grain fragments. It appeared that there were two areas of irregular break up contributing to these differences; one at approximately 110° and the other at approximately 160°.

The fragment densities are plotted for the individual rounds and the average of the three rounds, Figure 3, Inclosure 1. These plots show the highest densities to be in the rear section with the maximum value for steel fragments at an angle of 160° from the fuze end of the round, and 150° for the aluminum fragments. To show the effect of the small fragments (0-1 grain), densities were computed and plotted excluding these small fragments, Figure 4, Inclosure 1. These charts show that the greatest effect of the 0-1 grain fragments on density occurred at the fuze end, from approximately 0° - 10° for the steel fragments and to an even greater degree, from approximately 130° - 180°, for both steel and aluminum. Since no aluminum fragments were recovered from approximately 0° - 70°, this indicates that the aluminum body probably caused secondary breakup of the steel fragments from the warhead.

In obtaining fragment velocities, there was a slight indication of a bimodal distribution of the photographic velocities from approximately 120° - 160°, presumably due to the presence of steel and aluminum fragments. In an attempt to obtain more information on velocity levels of the two types of fragments, extra velocity panels (4 ft x 8 ft) were placed above the corner sections of the recovery area, i.e., at angles of 45° and 135° for Round No. 3. These panels were installed with cellotex behind them to enable recovery of the fragments perforating the dural sheets, thus providing association of the fragment type and weight with velocity. However, insufficient data were obtained to add any information about the aforementioned bimodal distribution.

For the extra panel at 135°, 154 perforations were recorded, of which 84 were identified with steel fragments and 7 with aluminum fragments, with the end result that velocities were obtained for 36 steel fragments and only 2 aluminum fragments. Nevertheless, while the data from the extra panels did not enable separation of steel and aluminum fragment velocities, the data substantiated the wide dispersion of photographic velocities, approximately 2500 fps (3000-5500 fps) encountered on the normal velocity panels for the corresponding angle and further showed that this dispersion of velocities was occurring with the steel fragments. The small number of aluminum fragments identified for the extra panel was apparently due to the inability of the aluminum fragments to perforate the shell of dural.

For the extra velocity panel at 45°, only steel fragments were recovered. The total number of perforations for this panel was 43, for which 30 fragments were recovered. Velocities were obtained for 27 of these fragments. The velocity results for this panel also substantiated the velocity dispersion occurring with the corresponding normal velocity targets.

Since no separation of the photographic velocities was possible for the two types of metal, the initial velocities were computed using the drag characteristics for steel fragments. These initial velocities were then considered applicable to both steel and aluminum fragments. This method appeared most practical in view of the configuration of the round in which the explosive charge was confined by the steel warhead with aluminum body several inches away from the charge.

In computing the initial velocities, the representative fragment weight, m_r, was computed as the fragment weight corresponding to the median of the number of fragments recovered after tabulating the weight data by weight intervals and excluding fragments in the 0-1 grain weight interval and a few large fragments. While the usual procedure for determining the representative fragment weight is to compute the fragment half-weight for each zone, the computed fragment half-weights for these rounds were relatively large and appeared to represent a much lower number of fragments than the number of velocities obtained for each zone. The values of m_r thus determined by finding the median of the modified number of fragments recovered were influenced very little by any one fragment, and exhibited less variation from zone to zone, than the values obtained using the fragment half-weight method. For all three rounds the values of m_r used in computing initial velocities varied from 1.60 to 10.00 grains.

To illustrate the difference in representative fragment weights obtained by the two methods, the data from Round 3, Zone 6, (angular interval 45° - 55°) are given. In this zone, 73 steel fragments of which 45 weighed less than 1 grain, were recovered, and 41 velocities were read from the film. Use of the fragment half-weight method resulted in a weight of 21.18 grains for m_r as compared to a weight of 4.45 grains obtained by the method based on the number of fragments. Since only five fragments weighed 20 grains or more, it was felt that this weight did not represent those fragments for which velocities were obtained. Computation of initial velocity using these two weights would result in a difference of approximately 700 fps (i.e. 5550 and 4850 fps for 4.45 and 21.18 grains, respectively).

In determining the number of fragments N(m) for the entire round greater than weight (m) according to Mott's Law, it was found that the relation N(m) vs $m^{1/3}$ produced a better fit than N(m) vs $m^{1/2}$ for the steel fragments. The resulting equation for the steel fragments, $\text{Log}_{10}\, N(m) = 4.943 - .61723\, m^{1/3}$, was determined excluding fragments greater than 400 grains which amounted to considerably less than 1% of the total number, see Figure 9, Inclosure 1. The above equation agrees with the observed values very well for weights from 1 to 400 grains, but gives values too high for fragments weighing less than 1 grain.

A similar relationship was determined for the aluminum fragments, Figure 10, Inclosure 1, and is expressed by the equation $\text{Log}_{10}\, N(m) = 4.201 - .51053\, m^{1/3}$. This equation agrees well with the observed results of m from 0 - 50 grains. Fragments weighing more than 50 grains, for which the equation gives values too high, were not used in determining the above equation.

(S) CONCLUSIONS

Based on the results of this test the subject XM-390 Projectile, Comp B loaded having a pearlitic malleable iron warhead of 50,000 psi yield strength, will produce approximately 70,000 steel fragments and 15,000 aluminum fragments of which approximately 70% of each type will be fragments weighing less than one grain.

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2 Incls
Incl 1
Figure 1 - Sketch of Fragmentation Arean (1p)
Figure 2 - Plots of Initial Velocity vs Angle (1p)
Figure 3 & 4 - Plots of Fragment Density vs Angle (2p)
Figure 5 & 6 - Graphs showing % Weight and Number vs Weight Interval (2p)
Figure 7 - Plot of Scaled Integrated Number vs Angle (1p)
Figure 8 - Plot of Accumulated Number vs Angle (1p)
Figure 9 & 10 - Plots of N(m) vs $m^{1/3}$ (2p)
Incl 2
Tabulated Data (35p)

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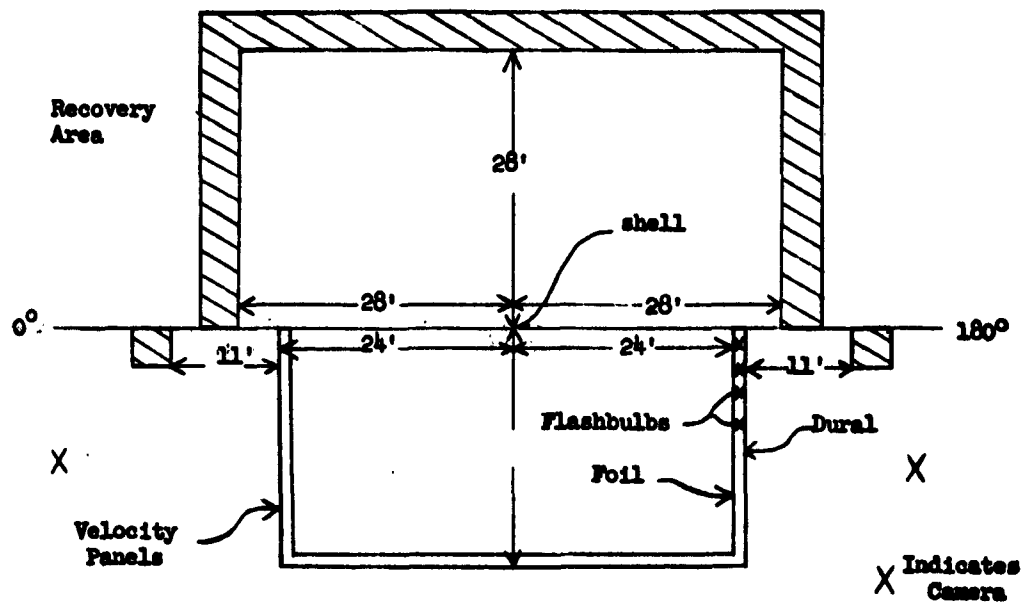
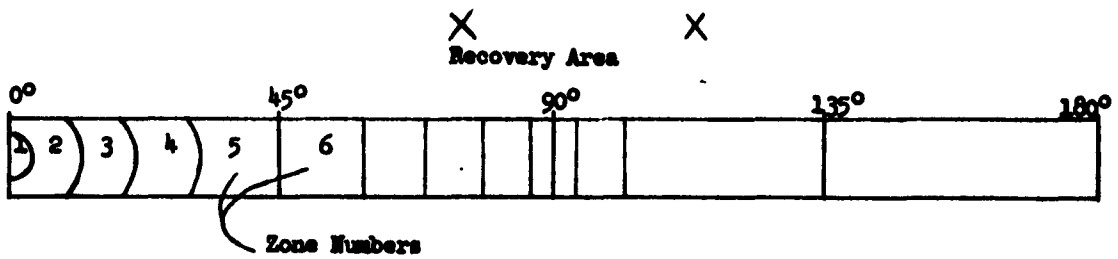
Fragmentation Arena





Velocity Area

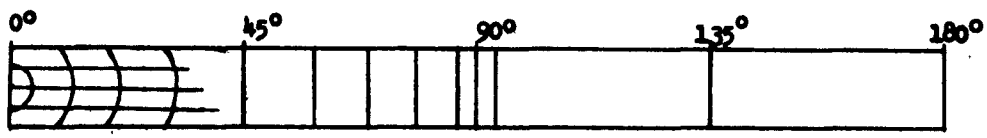


Fig 1, Incl 1

Anal Lab, Engr Labs, DASD

Fragment Initial Velocity, V_o, vs Angle θ
Individual Rounds and Average
279-mm Projectile, XM390

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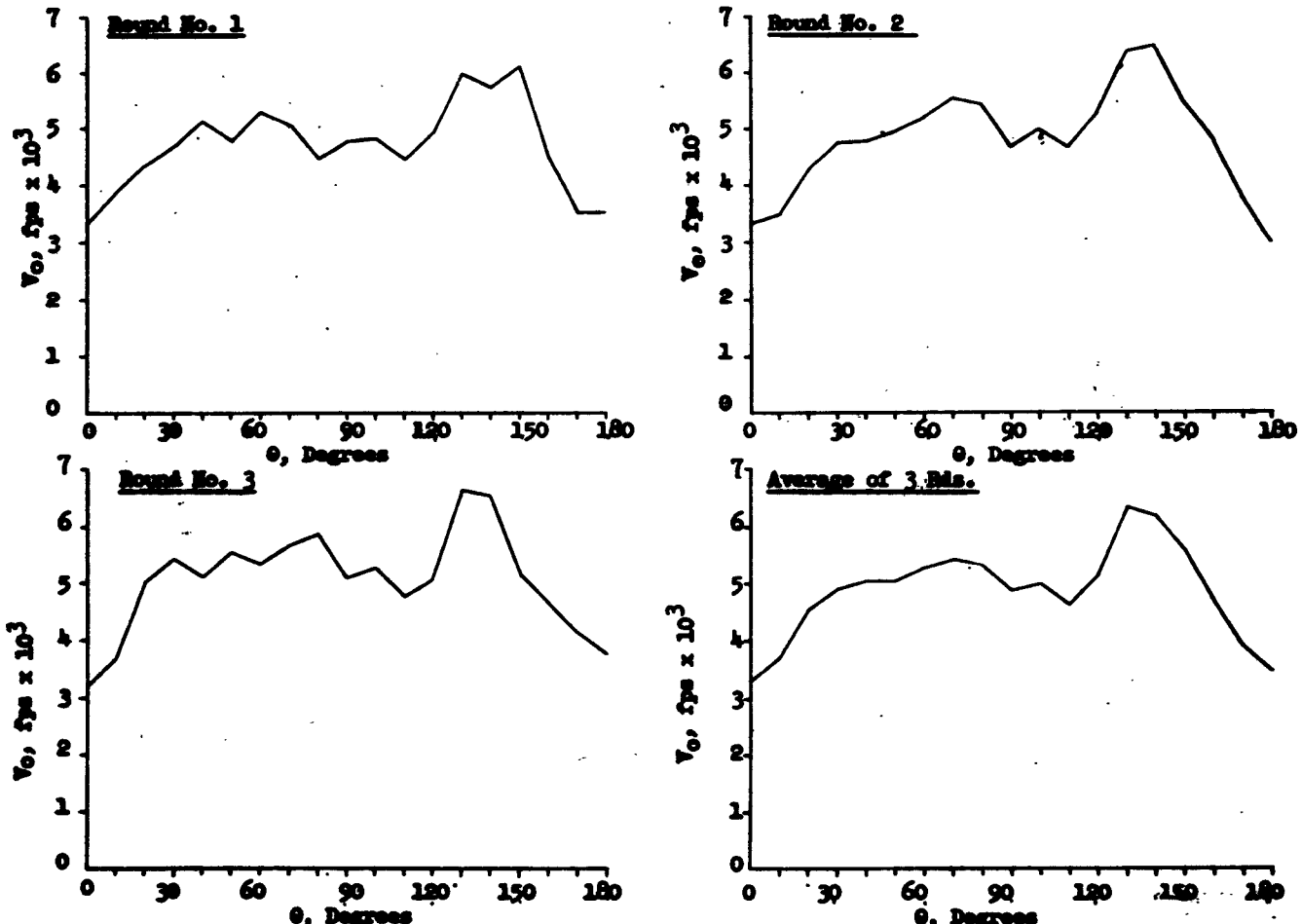

Fig 2, Incl 1

Angle θ Measured From Fuse End of Projectile

Anal Lab, Engr Labs, DARS

SECRET

Fragment Density, σ, vs Angle θ
Individual Rounds and Average
279-mm Projectile, XM390

60-AL-34
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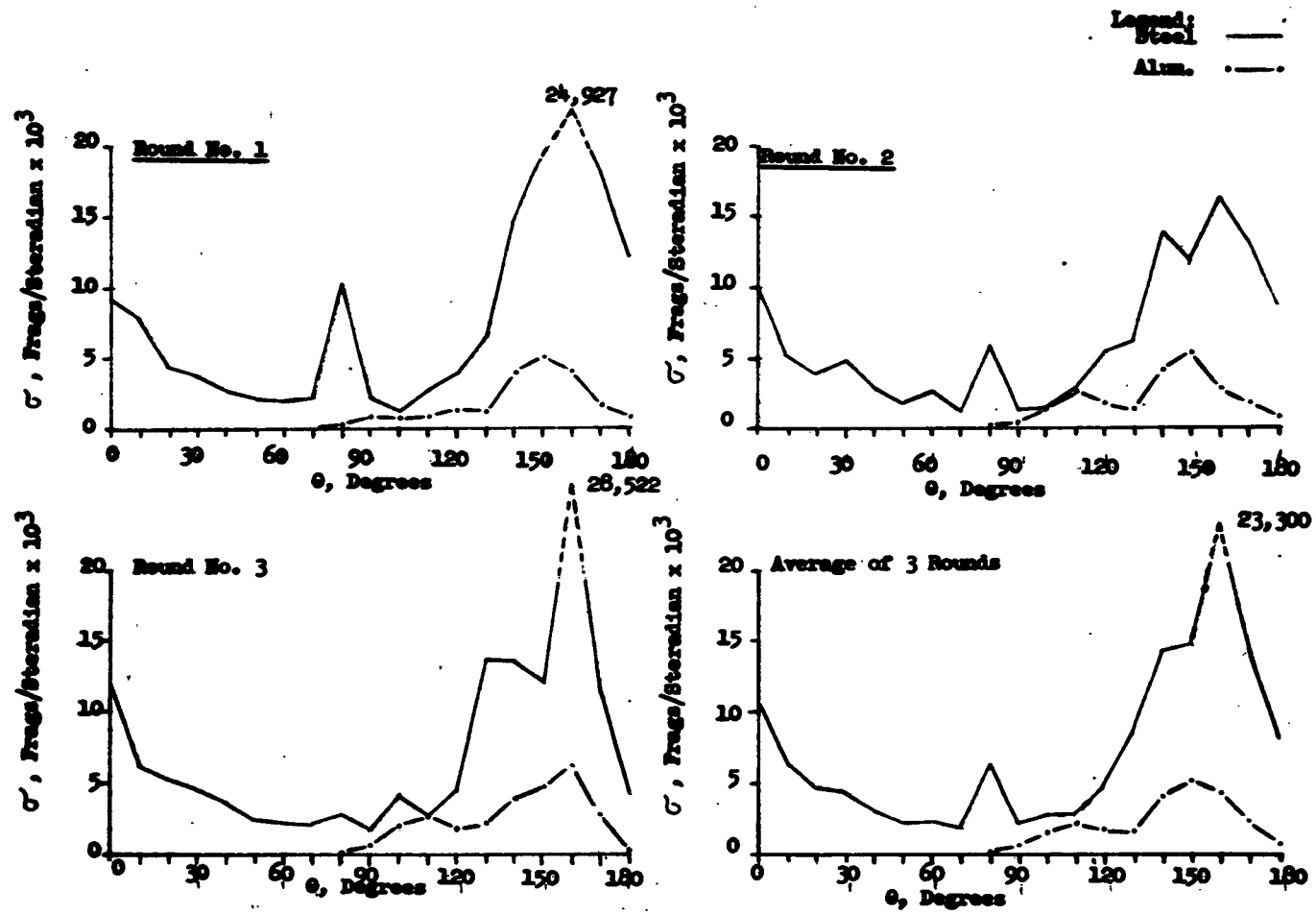

Angle θ Measured From Fuse End of Projectile

Fig 3, Encl 1

Anal Lab, Engr Labs, DARE

SECRET

Comparison of Fragment Densities, σ', vs Angle θ
Showing Effect of Fragments Weighing 0-1 grain
279-mm Projectile, M90
Average of Rds. 1, 2 and 3

60-AE-34
13

23,300

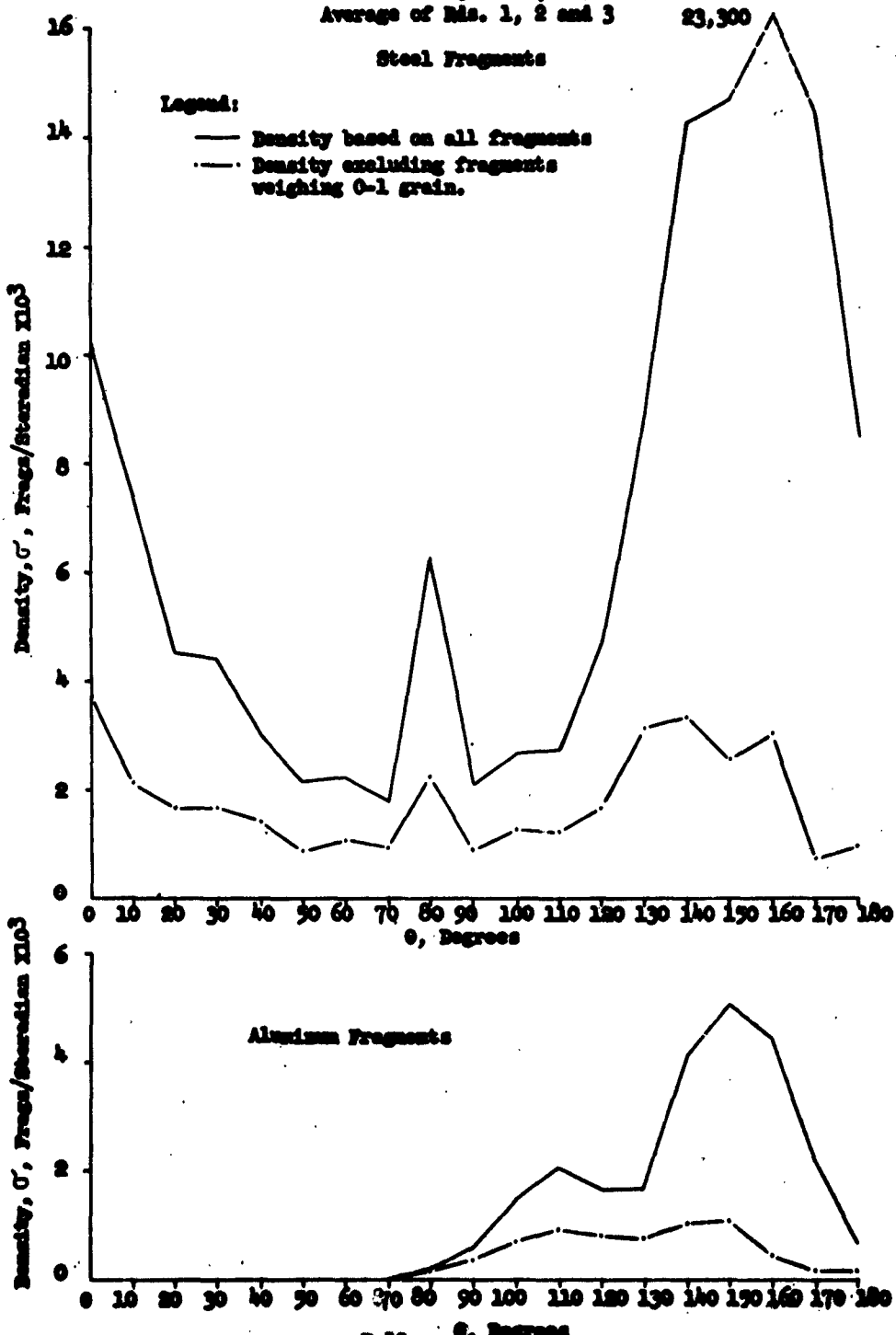

Fig 4, Incl 1

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Percent Weight and Number (qm, qn) vs Weight Interval
279-mm Projectile, XM390

Average of Rounds 1, 2, & 3
Steel Fragments

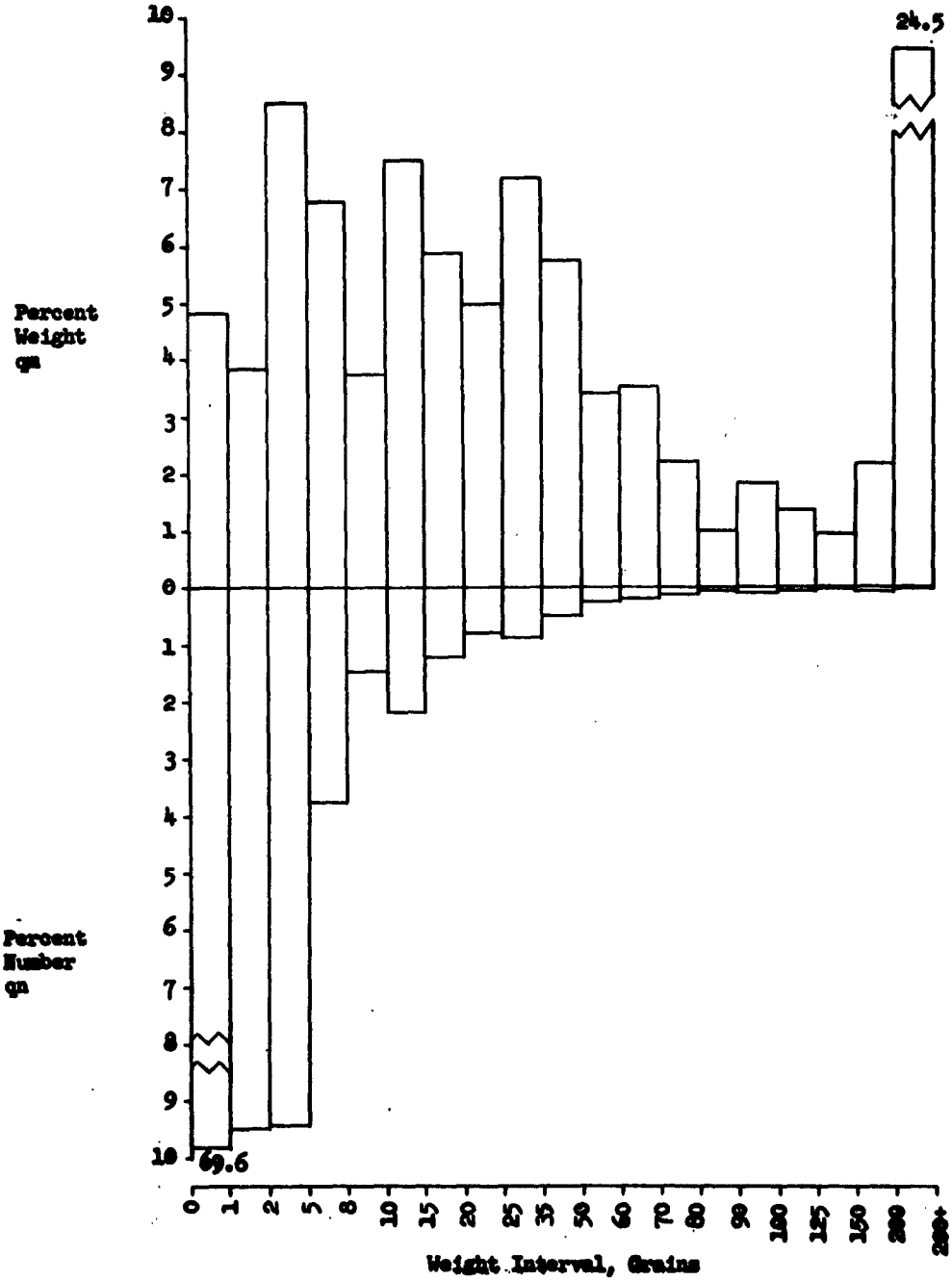
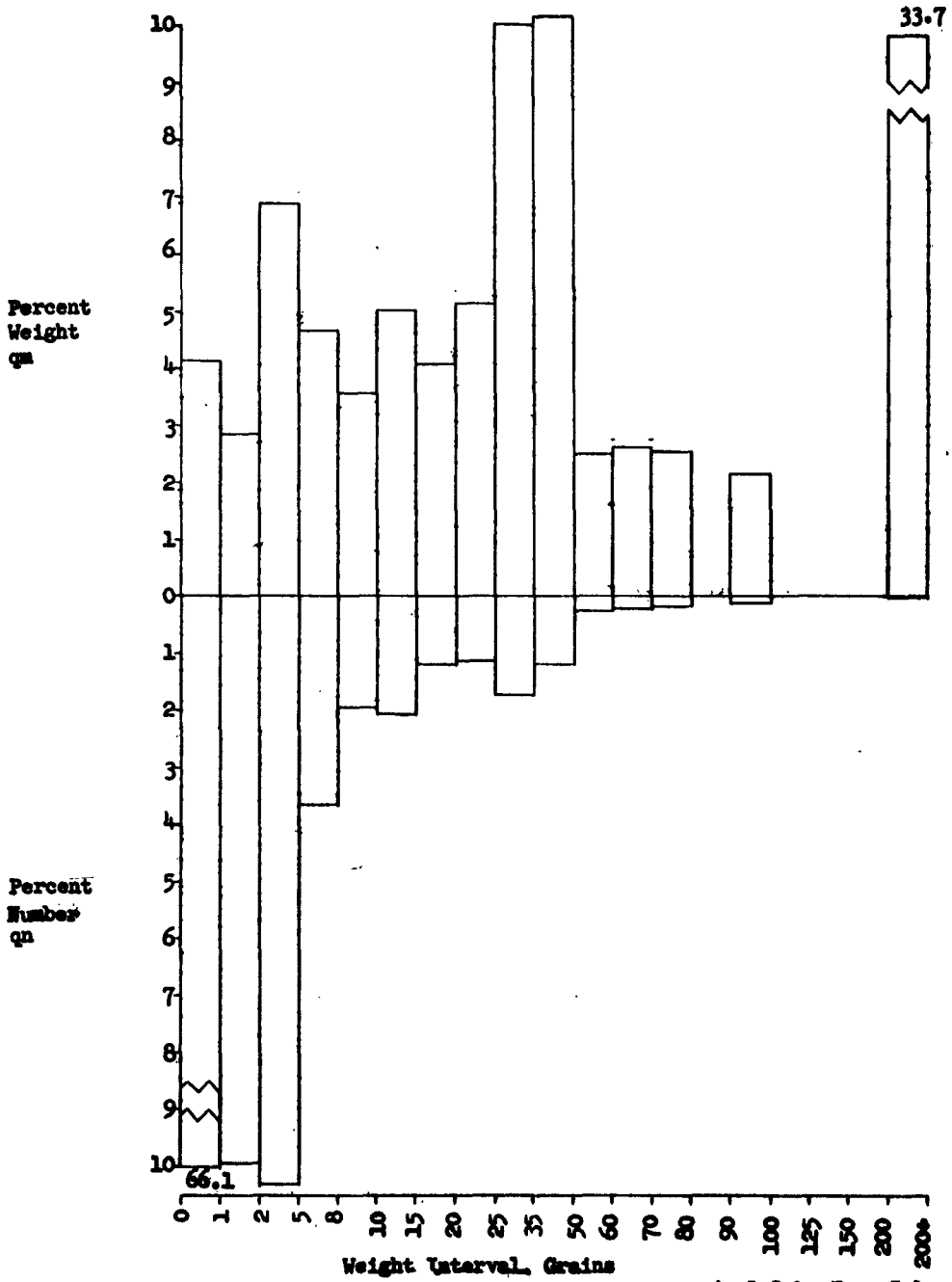


Fig 5, Incl 1

Percent Weight and Number (qm, qn) vs Weight Interval 60-AL-34
279-mm Projectile, XM390 15

Average of Rounds 1, 2, & 3
Aluminum Fragments



Anal Lab, Engr Labs, DAPG

Fig 6, Incl 1

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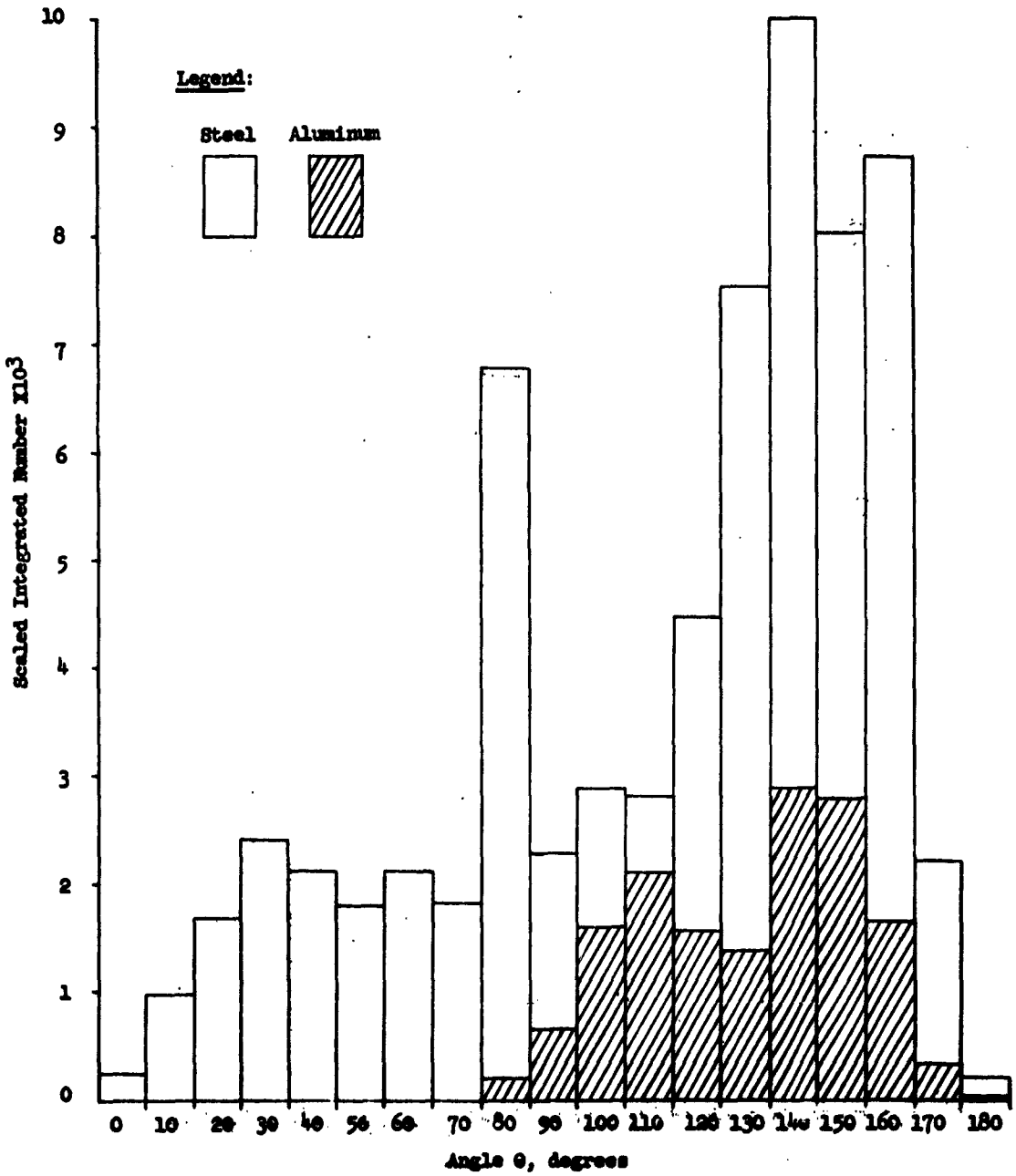
Scaled Integrated Number of Fragments
vs
Angle θ
279-mm Projectile, XM390
Average of Rds. 1, 2 and 3



Incl 1, Figure 7

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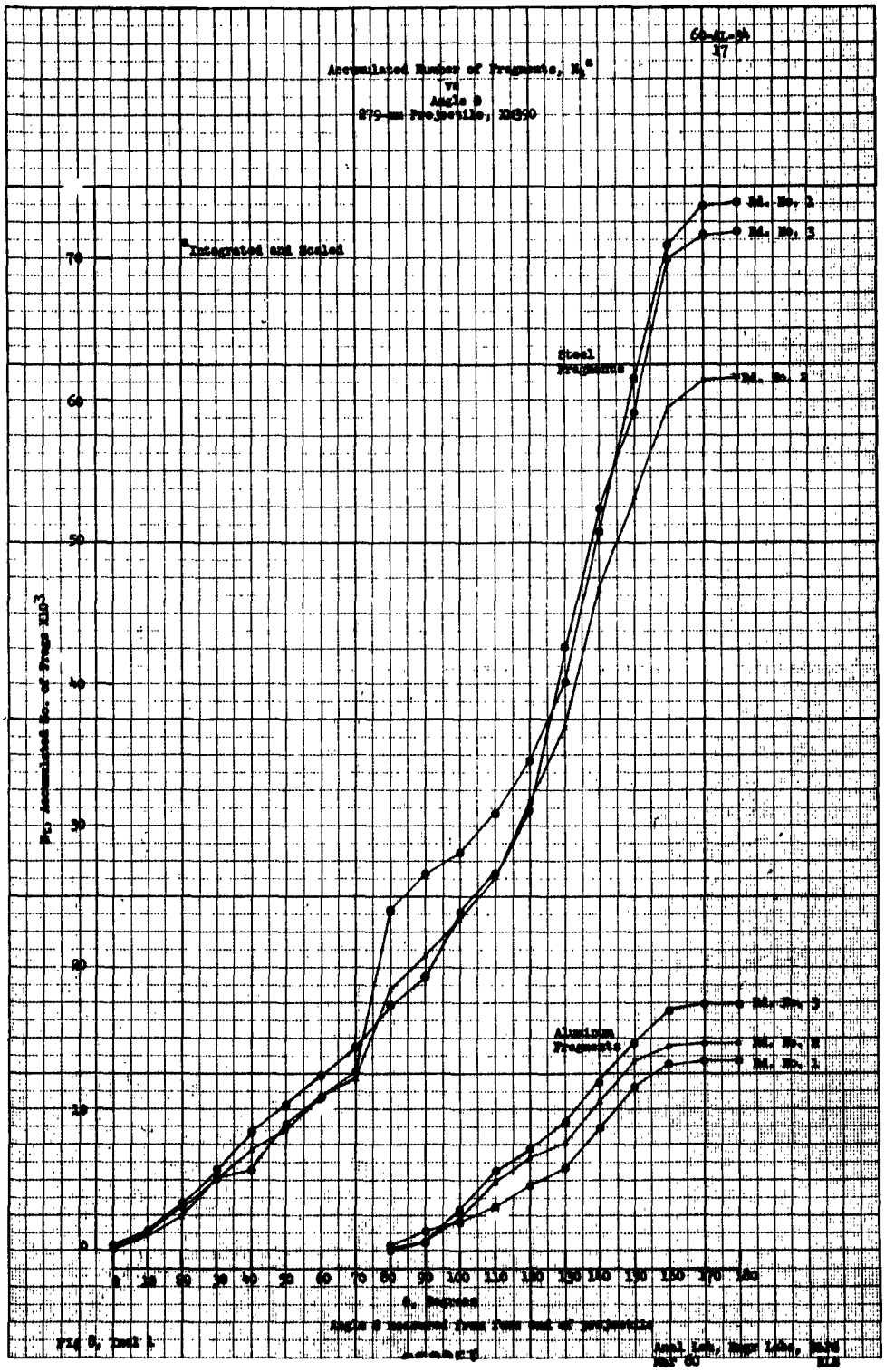
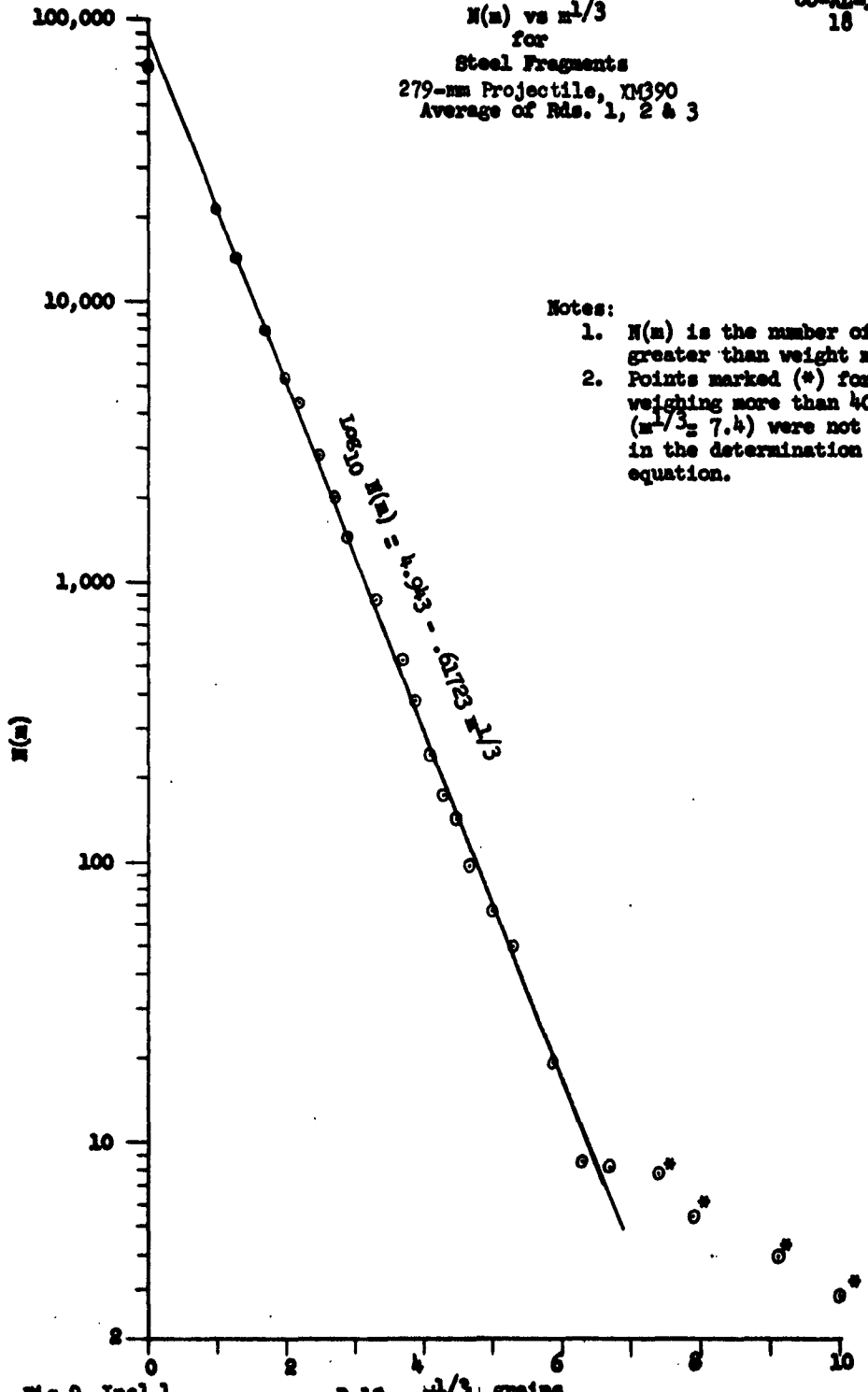

Accumulated Number of Fragments, N_θ
vs
Angle θ
279-mm Projectile, M82
Integrated and Scaled
Steel Fragments
Aluminum Fragments
θ, Degrees
Angle θ measured from nose end of projectile

Fig 8, Part 1

N(m) vs $m^{1/3}$
for
Steel Fragments
279-mm Projectile, XM390
Average of Rds. 1, 2 & 3



Notes:
1. N(m) is the number of fragments greater than weight m.
2. Points marked (*) for fragments weighing more than 400 grains ($m^{1/3} = 7.4$) were not included in the determination of the equation.

Fig 9, Incl 1

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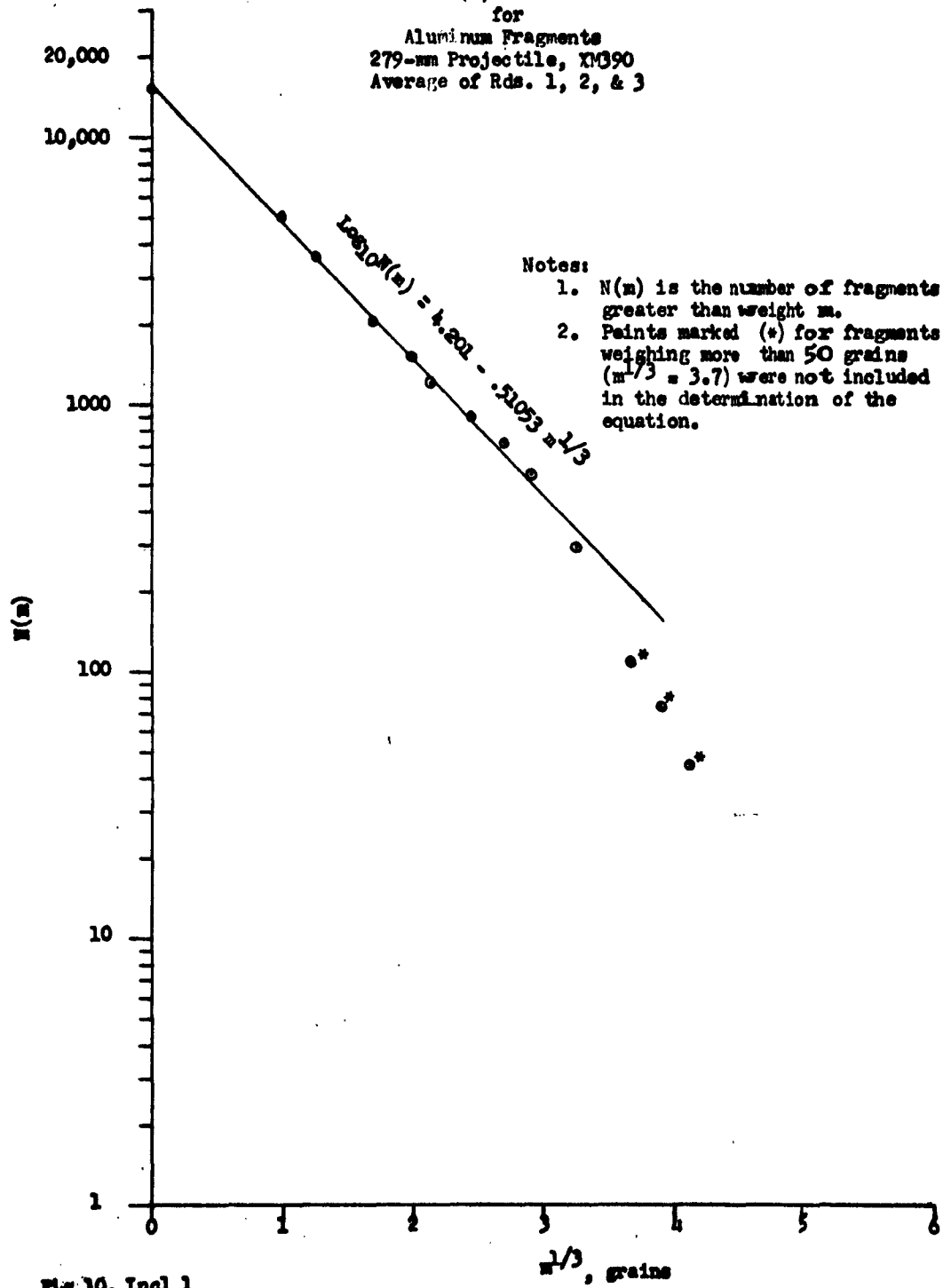
$N(m)$ vs $m^{1/3}$
for
Aluminum Fragments
279-mm Projectile, XM390
Average of Rds. 1, 2, & 3



Notes:
1. N(m) is the number of fragments greater than weight m.
2. Points marked (*) for fragments weighing more than 50 grains ($m^{1/3} = 3.7$) were not included in the determination of the equation.

Fig 10, Incl 1

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Fragment Velocity and Density

Average of Rd. Nos. 1, 2, & 3 Date of Firing: 30 Dec 1959, 12, 25 Jan 1960
Steel Fragments

θ Degrees	Initial Velocity, V_o fps	σ Density, Frags/Steradian
0	3300	10287
10	3700	6324
20	4550	4525
30	4900	4414
40	5050	3032
50	5050	2145
60	5300	2239
70	5450	1785
80	5350	6272
90	4900	2095
100	5000	2672
110	4650	2735
120	5150	4713
130	6350	8963
140	6200	14206
150	5600	14638
160	4700	23300
170	3950	14363
180	3500	8491

In the equation $V_r = V_o e^{-\frac{ar}{m^{1/3}}}$
where V_r and V_o are velocities in feet per second, m is weight in grains, and r is distance in feet,

a = .029 for Standard Conditions

Percent Recovery = 80.5

Anal Lab, Engr Labs, DAPS
Mar 60 HLB

Fragment Velocity and Density

Average of Rd. Nos. 1, 2, & 3 Date of Firing: 30 Dec 1959, 12, 25 Jan 1960
Aluminum Fragments

θ Degrees	Initial Velocity, V_o fps	σ Density, Frags/Steradian
0-70	No Aluminum Fragments Recovered	
80	5350	192
90	4900	599
100	5000	1479
110	4650	2046
120	5150	1648
130	6350	1642
140	6200	4102
150	5600	5077
160	4700	4414
170	3950	2238
180	3500	698

In the equation $V_r = V_o e^{-\frac{ar}{m^{1/3}}}$
where V_r and V_o are velocities in feet per second, m is weight in grains, and r is distance in feet,

a = .053 for Standard Conditions

Percent Recovery = 74.9

Anal Lab, Engr Labs, DAPG
Mar 60 HLB

Fragment Velocity and Density

Round No. 1 Date of Firing: 30 Dec 1959

Steel Fragments

θ Degrees	Initial Velocity, V_o fps	σ Density, Frags/Steradian
0	3350	9047
10	3850	7751
20	4350	4385
30	4700	3706
40	5150	2620
50	4800	2379
60	5300	1993
70	5100	2212
80	4500	10205
90	4800	2381
100	4850	1323
110	4500	2665
120	4950	3985
130	6000	6649
140	5750	14952
150	6150	19664
160	4500	24927
170	3550	18341
180	3550	12148

In the equation $V_r = V_o e^{-\frac{ar}{m^{1/3}}}$
where V_r and V_o are velocities
in feet per second, m is weight
in grains, and r is distance in feet,

a = .029 for Standard Conditions

Percent Recovery = 80.9

Anal Lab, Engr Labs, D&PS
Mar 60 HLB

60-4L-3h
3h

Fragment Velocity and Density

Round No. 1 Date of Firing: 30 Dec 1959

Aluminum Fragments

θ Degrees	Initial Velocity, V_o fps	σ Density, Frags/Steradian
0-70	No Aluminum Fragments Recovered	
80	4500	371
90	4800	902
100	4850	767
110	4500	985
120	4950	1488
130	6000	1426
140	5750	4070
150	6150	5200
160	4500	4190
170	3550	1786
180	3550	855

In the equation $V_r = V_o e^{-\frac{ar}{m^{1/3}}}$
where V_r and V_o are velocities in feet per second, m is weight in grains, and r is distance in feet,

a = .053 for Standard Conditions

Percent Recovery = 83.2

Anal Lab, Engr Labs, DASD
Mar 60 MLB

60-4L-34
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Fragment Velocity and Density

Round No. 2 Date of Firing: 12 Jan 1960

Steel Fragments

θ Degrees	Initial Velocity, V_o fps	σ Density, Frags/Steradian
0	3350	9728
10	3500	5061
20	4300	3973
30	4750	4942
40	4800	2757
50	4950	1728
60	5200	2522
70	5550	1136
80	5450	5847
90	4700	2163
100	5000	2461
110	4700	2881
120	5300	5464
130	6400	6370
140	6500	13851
150	5500	11825
160	4850	16450
170	3800	13052
180	3000	8975

$$- \frac{ar}{m^{1/3}}$$

In the equation $V_r = V_o e$
where V_r and V_o are velocities
in feet per second, m is weight
in grains, and r is distance in feet,

a = .029 for Standard Conditions

Percent Recovery = 77.8

Anal Lab, Engr Labs, D&PS
Mar 60 MLB

Fragment Velocity and Density

Round No. 2 Date of Firing: 12 Jan 1960

Aluminum Fragments

θ Degrees	Initial Velocity, V_o fps	σ Density Frags/Steradian
0-70	No Aluminum Fragments Recovered	
80	5450	116
90	4700	370
100	5000	1590
110	4700	2542
120	5300	1739
130	6400	1333
140	6500	4210
150	5500	5046
160	4850	2738
170	3800	1940
180	3000	998

In the equation $V_r = V_o e^{-\frac{ar}{m^{1/3}}}$
where V_r and V_o are velocities in feet per second, m is weight in grains, and r is distance in feet,

a = .053 for Standard Conditions

Percent Recovery = 71.2

Anal Lab, Engr Labs, DAPG
Mar 60 HLB

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Fragment Velocity and Density

Round No. 3 Date of Firing: 25 Jan 1960

Steel Fragments

θ Degrees	Initial Velocity, V_o fps	σ Density, Frags/Steradian
0	3200	12085
10	3700	6161
20	5000	5218
30	5450	4594
40	5150	3719
50	5550	2327
60	5350	2203
70	5700	2007
80	5900	2763
90	5100	1741
100	5300	4232
110	4800	2659
120	5100	4689
130	6650	13868
140	6550	13813
150	5200	12426
160	4700	28522
170	4700	11696
180	3800	4349

In the equation $V_r = V_o e^{-\frac{ar}{m^{1/3}}}$
where V_r and V_o are velocities in feet per second, m is weight in grains, and r is distance in feet,

a = .029 for Standard Conditions

Percent Recovery = 82.7

Anal Lab, Engr Labs, DASD
Mar 60 MLB